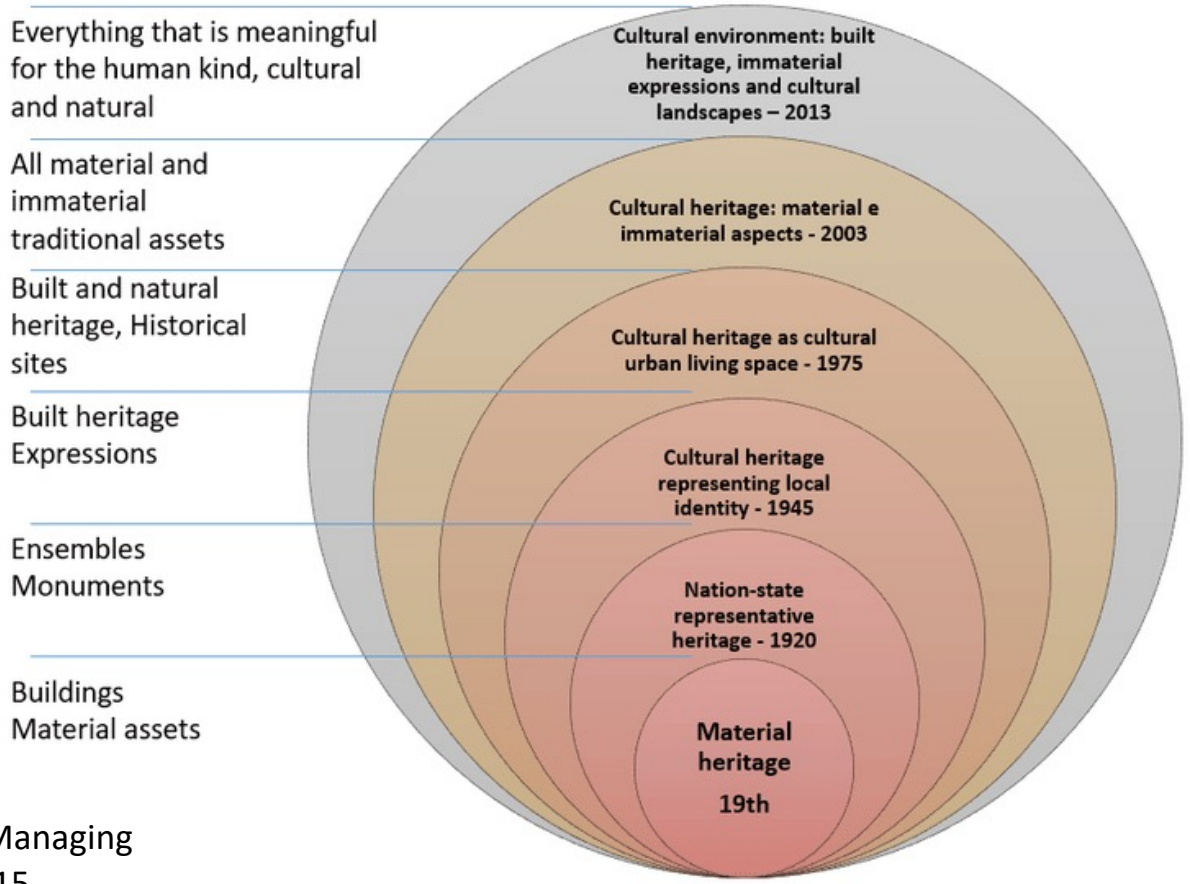
III. Analysis

8. Modelling and Analysis of Space and Time

Prof. Dr. Martin Langner

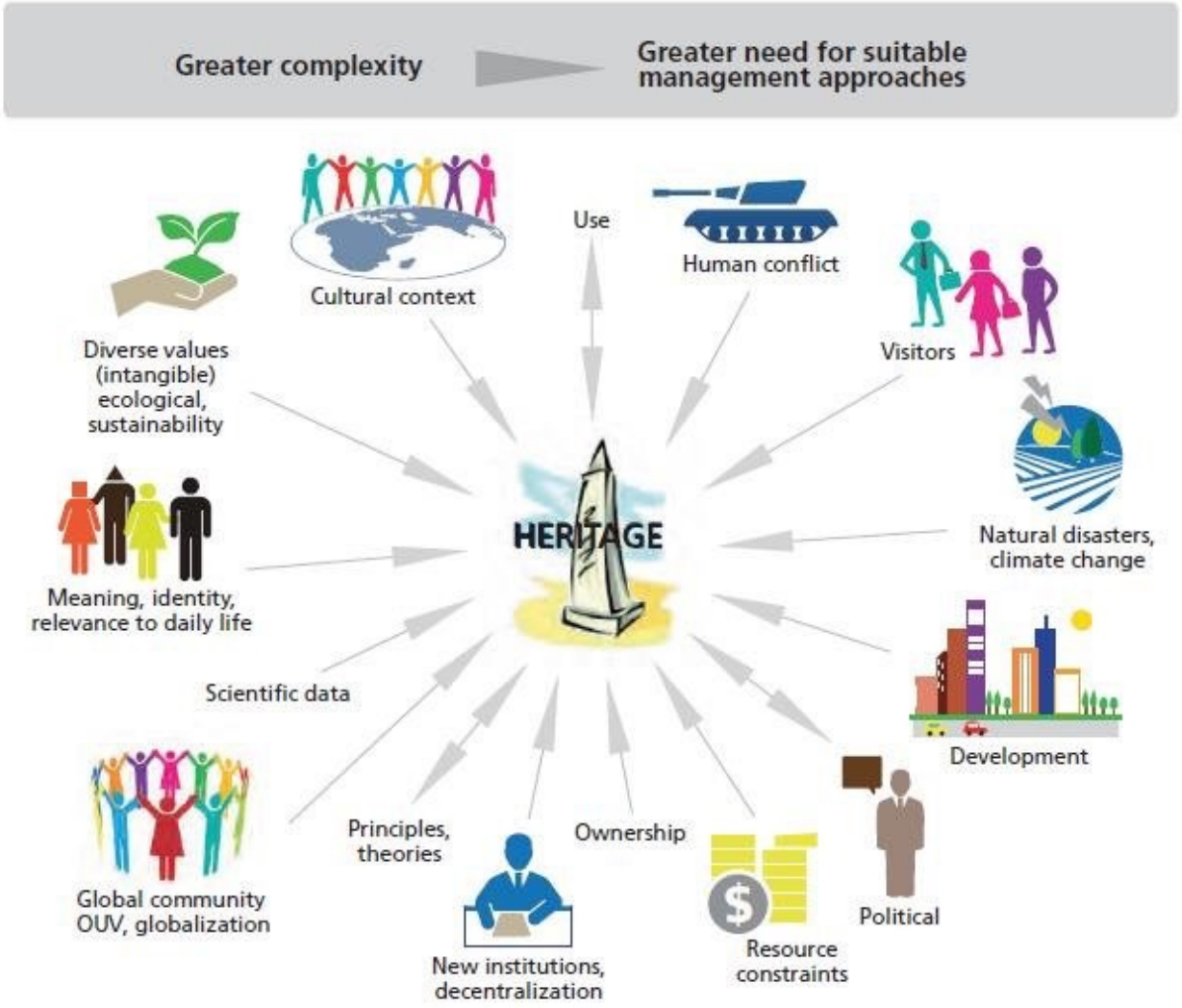
Schreibman / Siemens / Unsworth (2016) Kap. 14;
Jannidis / Kohle / Rehbein (2017) Kap. 21

THE CONCEPT „CULTURAL HERITAGE“



UNESCO, ICCROM, ICOMOS, IUCN, Managing cultural world heritage, Paris 2013, 15

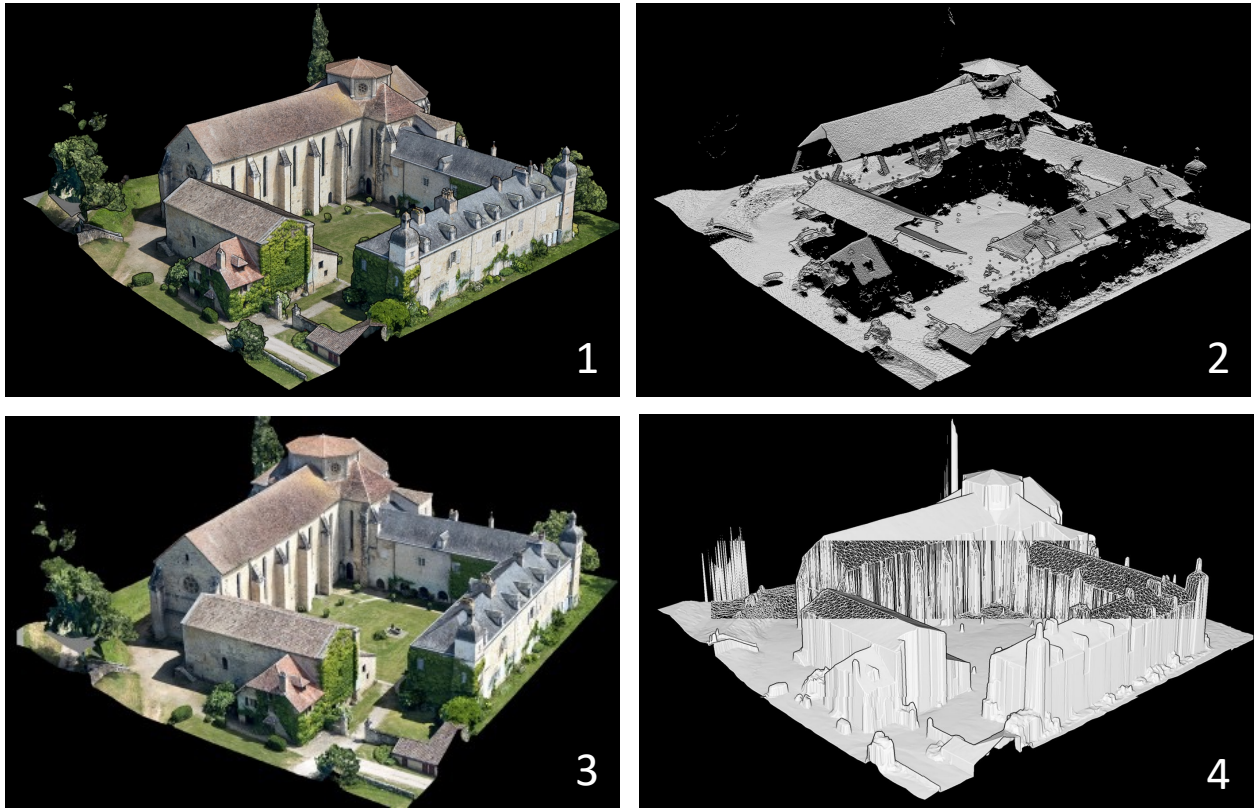
RELEVANT INFLUENCES ON CULTURAL HERITAGE



UNESCO, ICCROM, ICOMOS, IUCN, Managing cultural world heritage, Paris 2013, 15

Data representation of buildings in 3D models

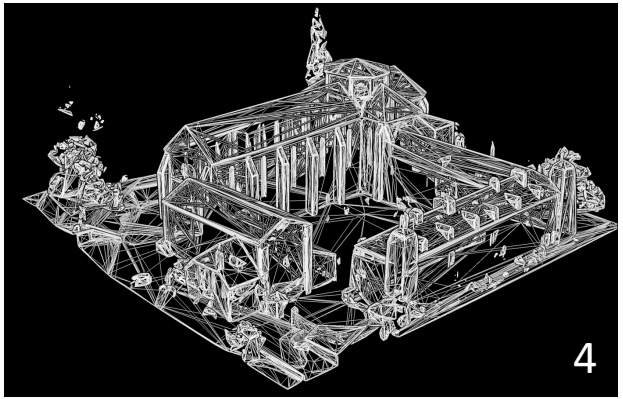
1. photogrammetrically acquired point cloud
2. LiDAR simulated point cloud
3. multi-view (RGB raster images)
4. mesh

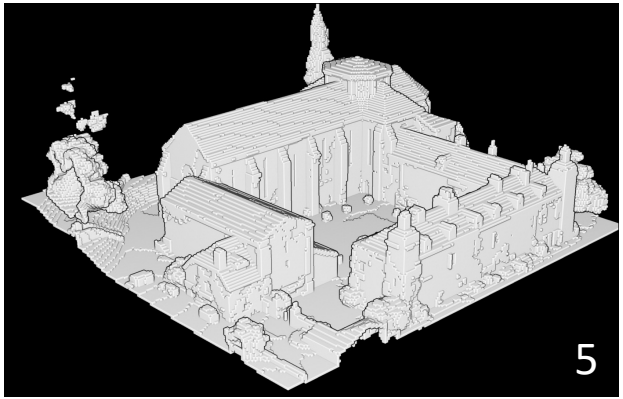


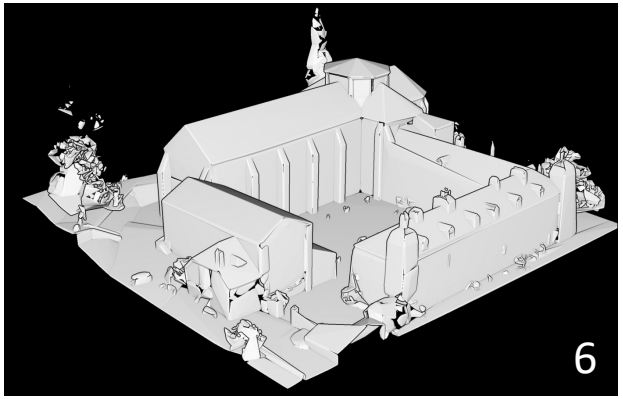
https://towardsdatascience.com/how-to-represent-3d-data-66a0f6376afb

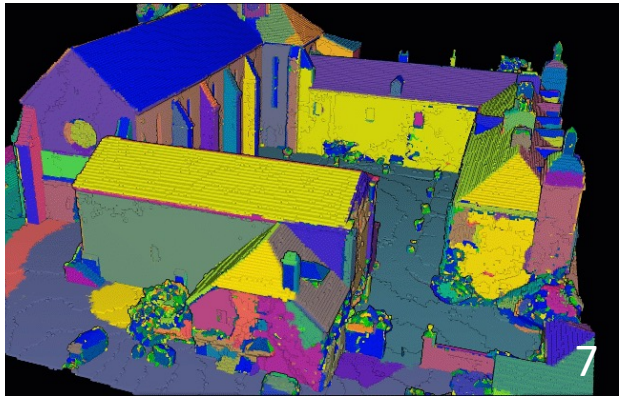
Data representations of buildings in 3D models

4. surface model (B-reps, mesh)
5. voxel model
6. parametric model (CAD)
7. automatic segmentation





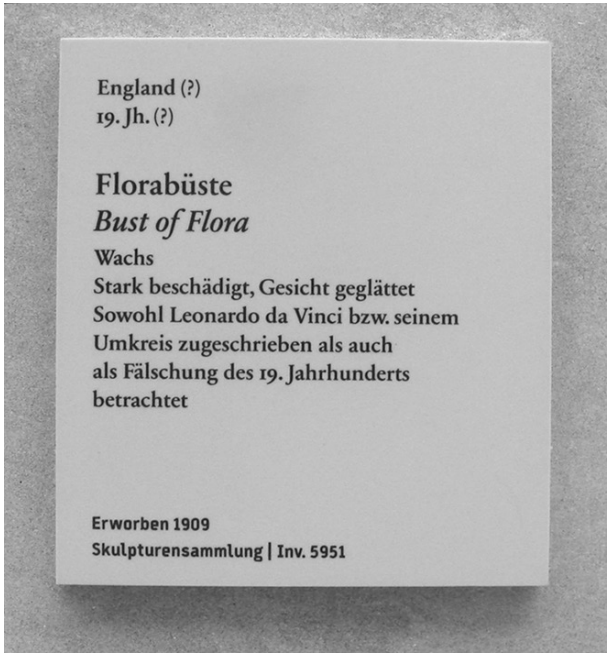




https://towardsdatascience.com/how-to-represent-3d-data-66a0f6376afb

Dating is very important for the construction of historical models, as historiography is based on the integrity of datable sources.

Precise (absolute) dates are rather rare until modern times. Dating is therefore mostly a process of estimation.



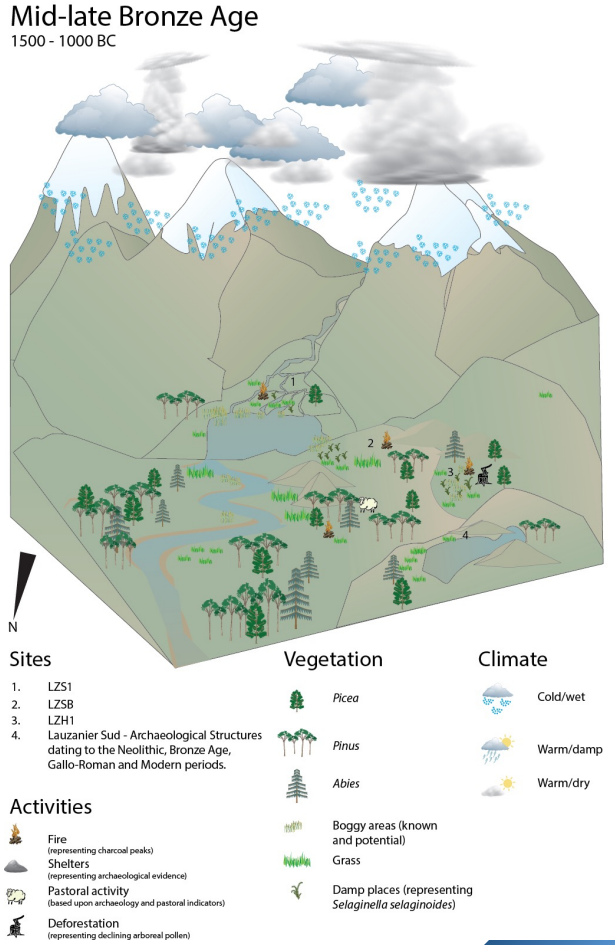
In general, there are four sources for dating:

- ancient literature and inscriptions
- archaeophysical or archaeochemical data
- stylistic series
- stratigraphic relationships

BEGINNINGS OF DIGITAL ARCHAEOLOGY

- Quantifying Archaeology
- New Archaeology (Processual Archaeology)
- Development of Geographic Information Systems (GIS)
- Environmental Archaeology

https://intarch.ac.uk/journal/issue53/afterword.html



Lewis R. Binford, "Archaeology as anthropology," in: M. Leone (ed.), *Contemporary Archaeology* (Carbondale 1962), 93–101; David Clarke, "Archaeology: the loss of innocence," *Antiquity* 47 (1973), 6–18; Manfred K.H. Eggert, *Prähistorische Archäologie. Konzepte und Methoden* (Tübingen / Basel 2001); Matthew Johnson, *Archaeological Theory. An Introduction*[2] (Oxford 2010)

1. DIGITAL EXCAVATION ARCHAEOLOGY

Geoprospecting

Excavation documentation

Geoarchaeology

Geoinformation systems

Geovisualisation

2. PROBLEMS WITH DATING

Date formats and chronological systems

Dating options

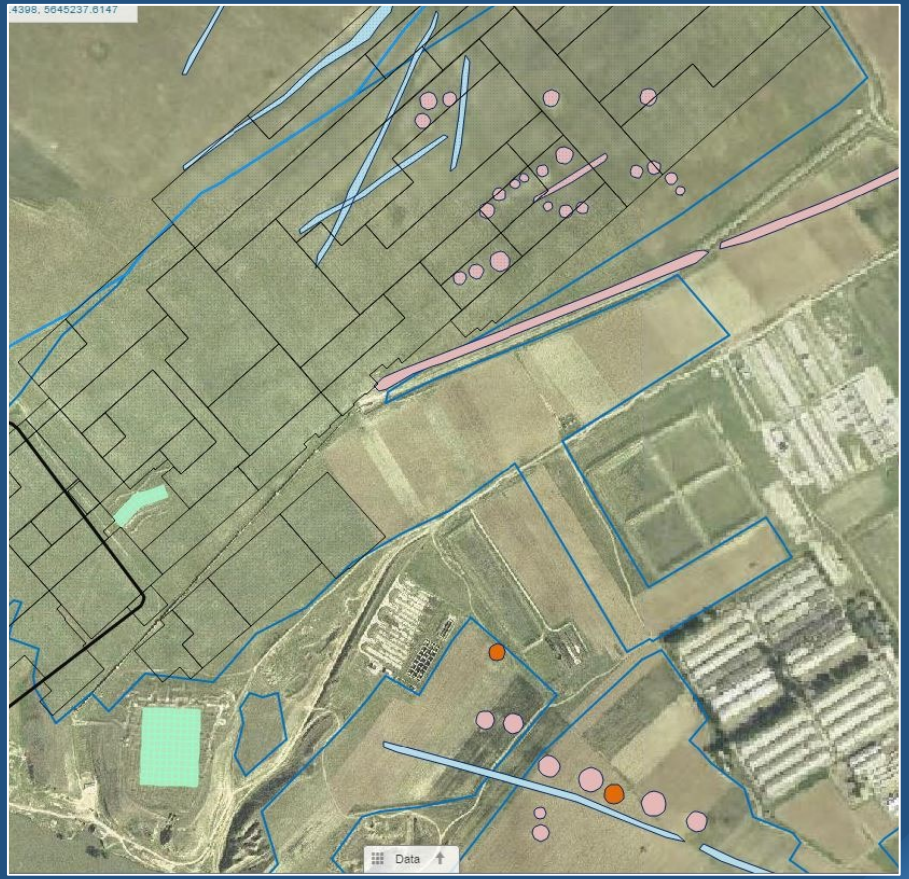
3. THE DIGITAL MODELLING OF SPACE AND TIME

Timeline

Fuzziness

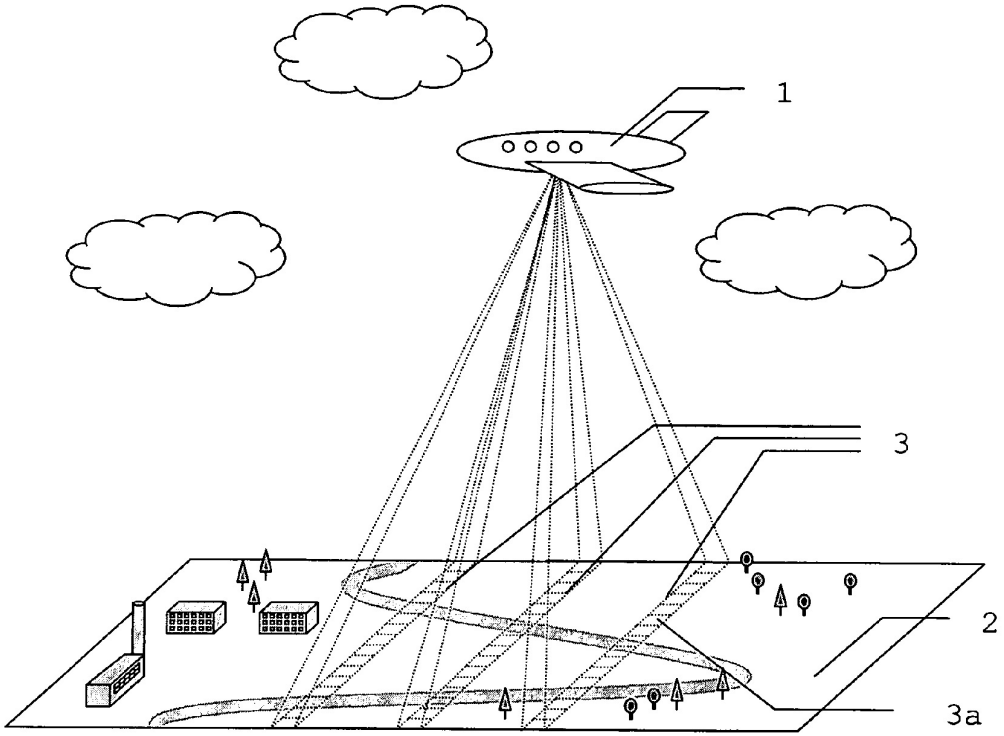
Seriation

DIGITAL EXCAVATION ARCHAEOLOGY



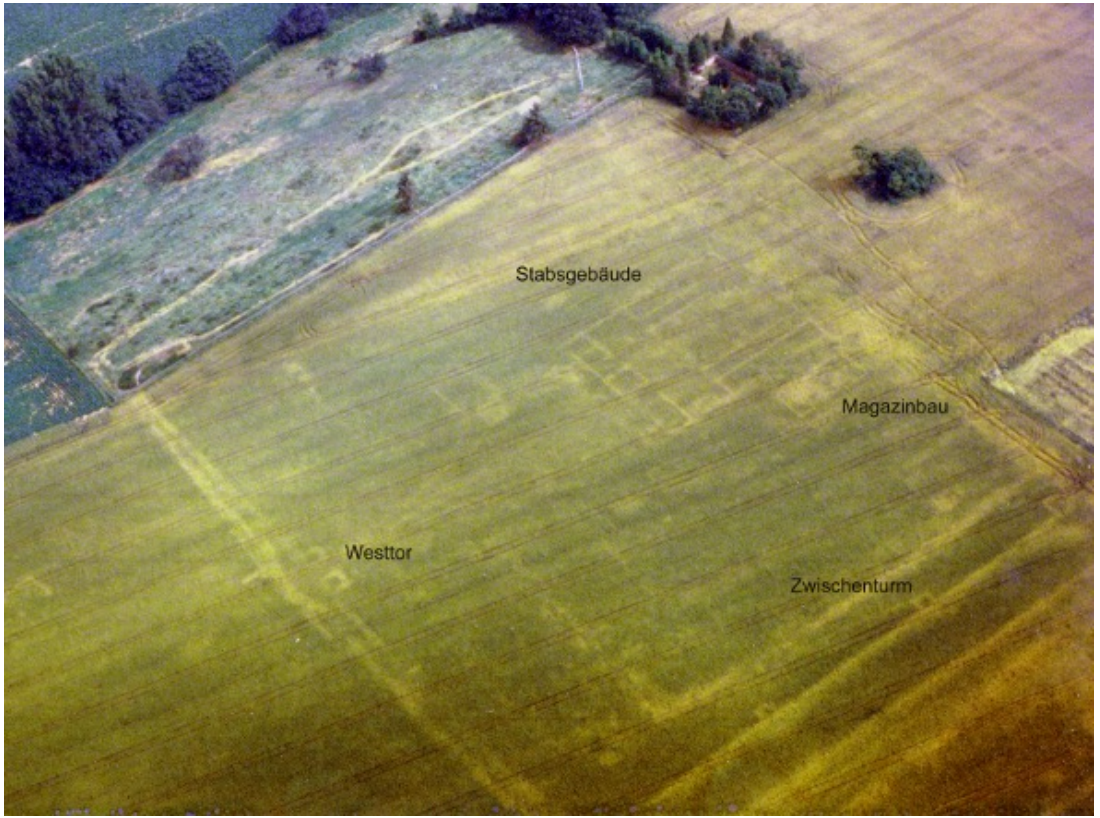
Airborne laser scanner (LIDAR)

- Laser pulse-based scanners with medium to long range (>2 metres focal distance), also known as time-of-flight scanners
- The systems use circuitry that measures, to the picosecond, the time it takes for the light to travel from the laser to the object and back to the sensor for millions of laser pulses, and calculates the distance from each.



AERIAL PHOTOGRAPHY

Underground remains can be identified by a slight discolouration of the soil, especially after rain. With the help of aeroplanes, helicopters, balloons or drones, these are photographed and evaluated from a greater height.



Fort Arnsburg from the air
http://www.aghessen.de/arnsburg-kastell/kastell.html

GEOMAGNETIC

By electromagnetically measuring anomalies in the (so-called normal) earth's field, magnetised rock bodies and objects can be determined in terms of position, depth and shape.

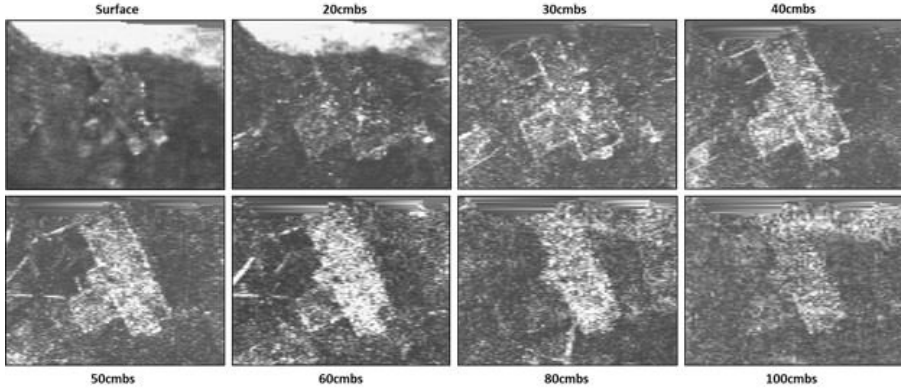
Fort Arnsburg in the measurement image of geomagnetics
http://www.aghessen.de/arnsburg-kastell/kastell.html

GROUND PENETRATING RADAR (GPR)

(GPR) uses electromagnetic radiation in the microwave band (UHF / VHF frequencies) of the radio spectrum.

Underground objects and stratigraphies cause reflections that are picked up by a receiver. The time of flight of the reflected signal indicates the depth.

https://www.geophysical.com/archaeology

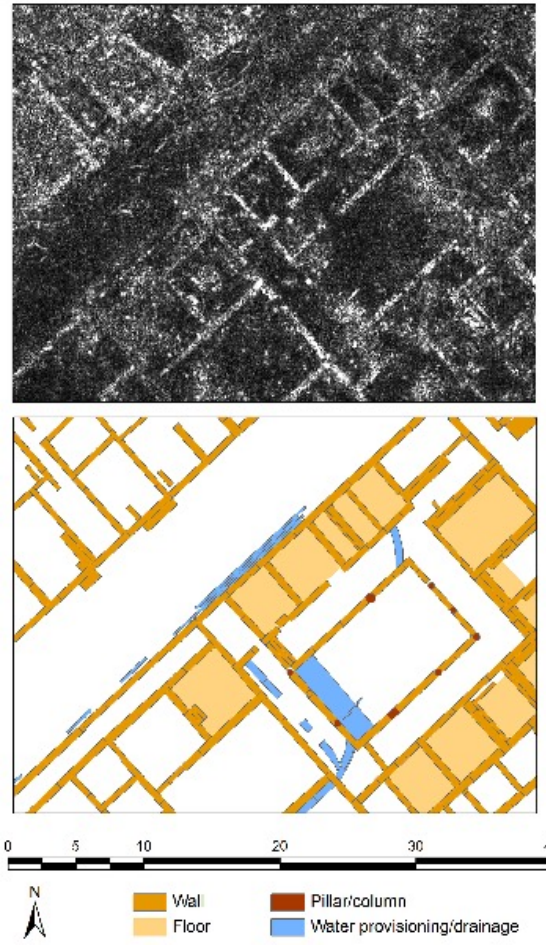


Jürg Leckebusch, *Die Anwendung des Bodenradars (GPR) in der archäologischen Prospektion. 3D-Visualisierung und Interpretation* (Rahden: Leidorf 2001)

GROUND PENETRATING RADAR

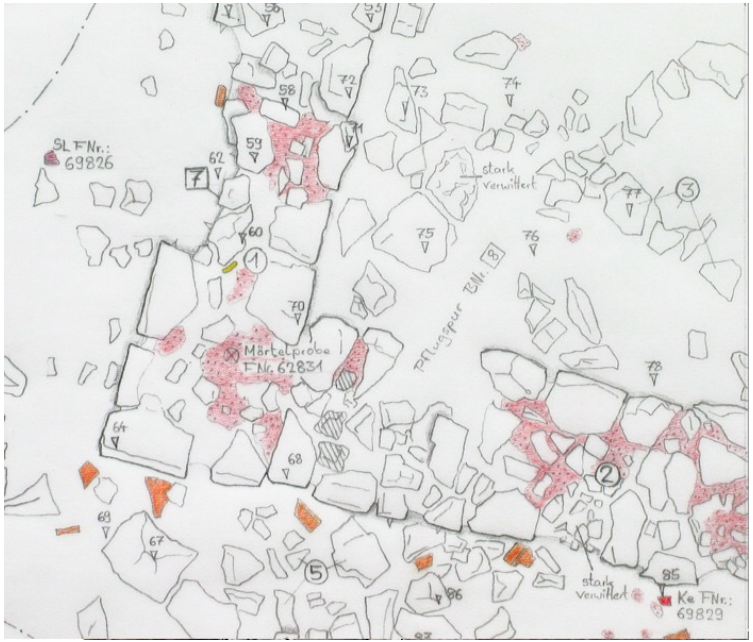
Data can be recorded as profiles, plan view maps or three-dimensional models.

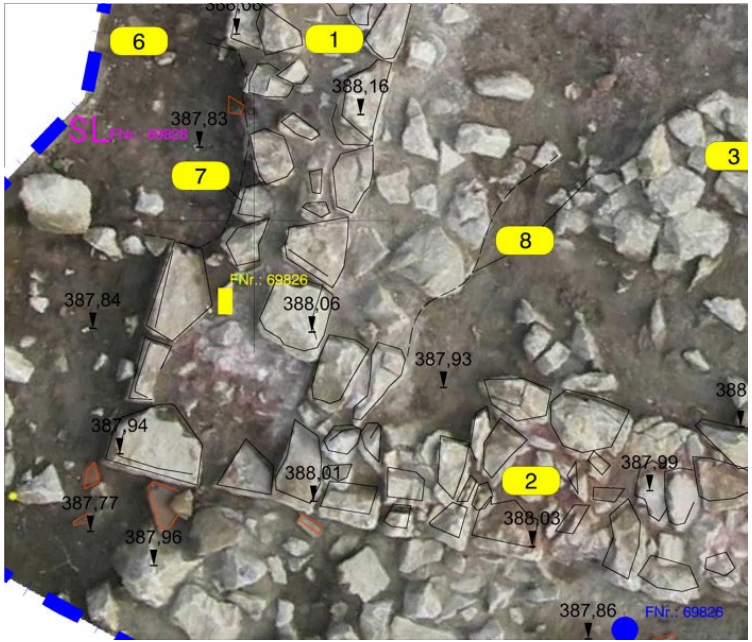
The electrical conductivity of the ground, the transmitted centre frequency and the radiated power can limit the effective depth range of the GPR survey.



Ammaia (Portugal), Georadar-slice (Tiefe: c. 0.60 - 0.65 m) and Interpretation (https://www.ugent.be/lw/archeologie/en/research/research-projects/medrom-groundpenetratingradar.htm)

DIGITAL DOCUMENTATION OF AN EXCAVATION

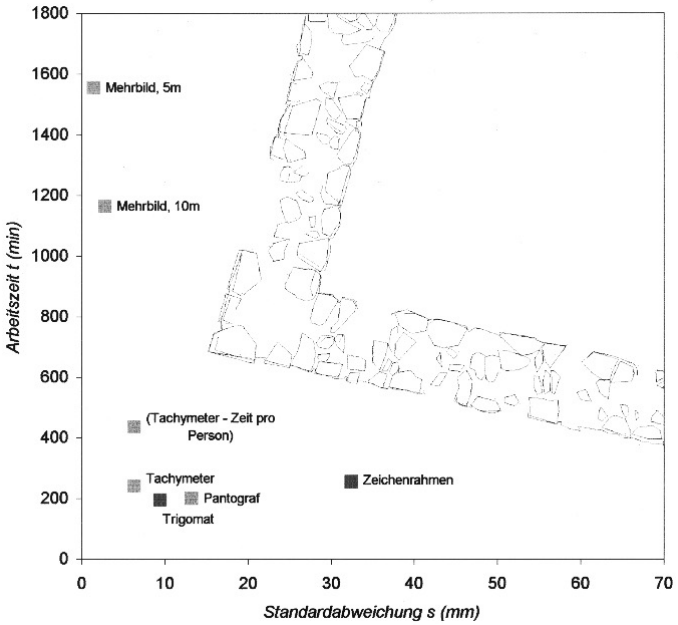




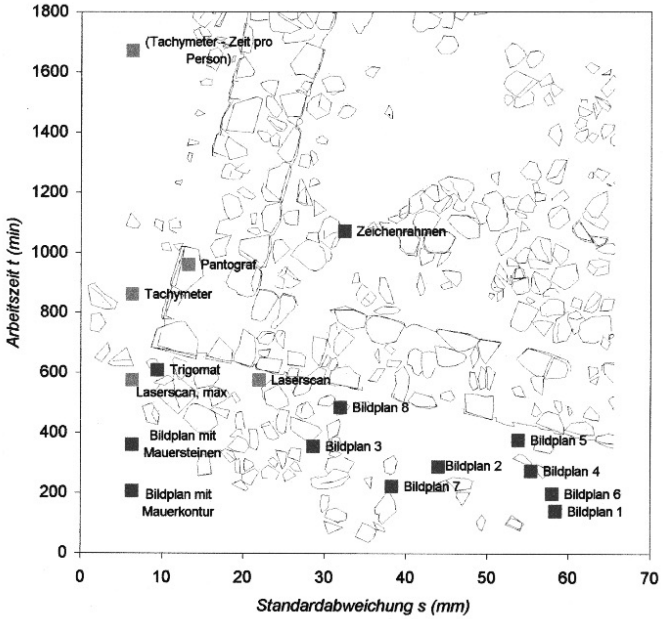
Example: Excavation of a villa rustica from Nassenfels, Eichstätt district. In the 8 x 9.5 m area lay the south-west corner of a stone outbuilding of the villa, surrounded by disordered rubble. The condition of the features corresponded to the 1st planum of the excavation.

Diagram accuracy - working time

Photogrammetric single image evaluation and representation as image plan



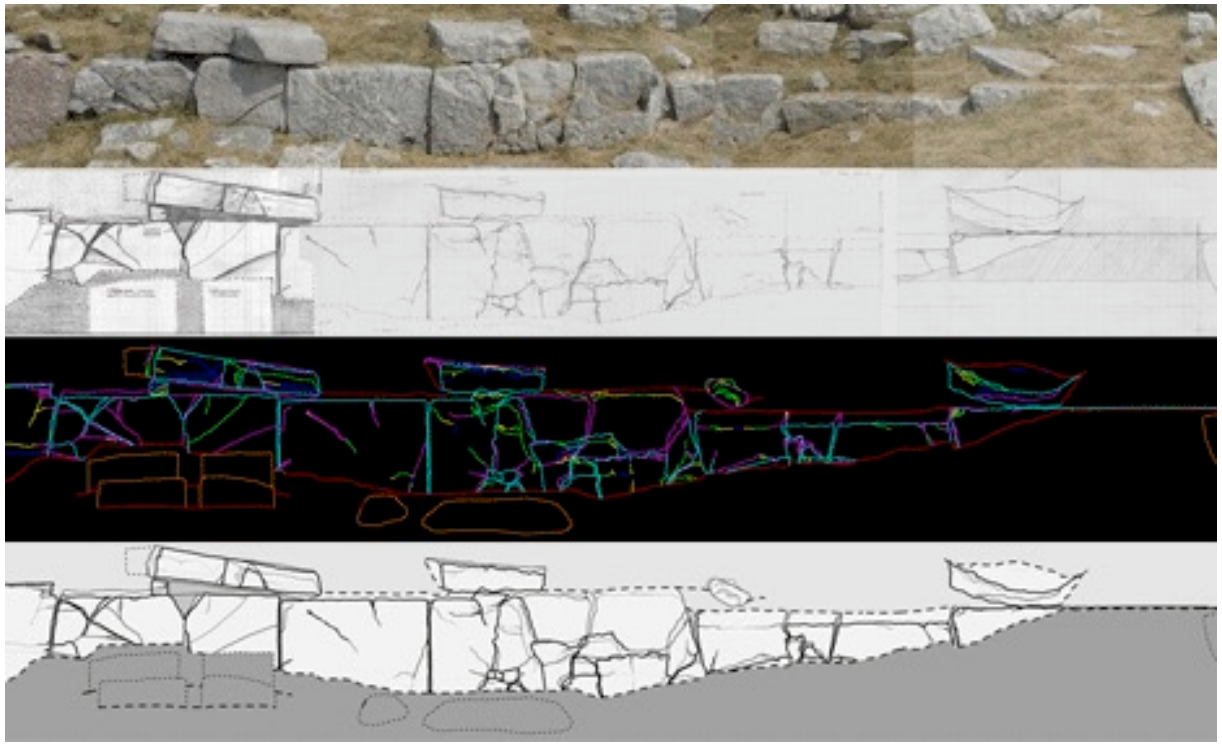
Exact acquisition of the wall without debris from the lintel



Exact acquisition of the wall with debris from the lintel

Tilman Wanke, Ein Vergleich verschiedener Aufnahmemethoden für die Archäologische Dokumentation (http://www.b-f-k.de/webpub01/cnt/wanke.htm)

CAD (Computer Aided Design)



Stoa on Mt. Lykaion in Arcadia:

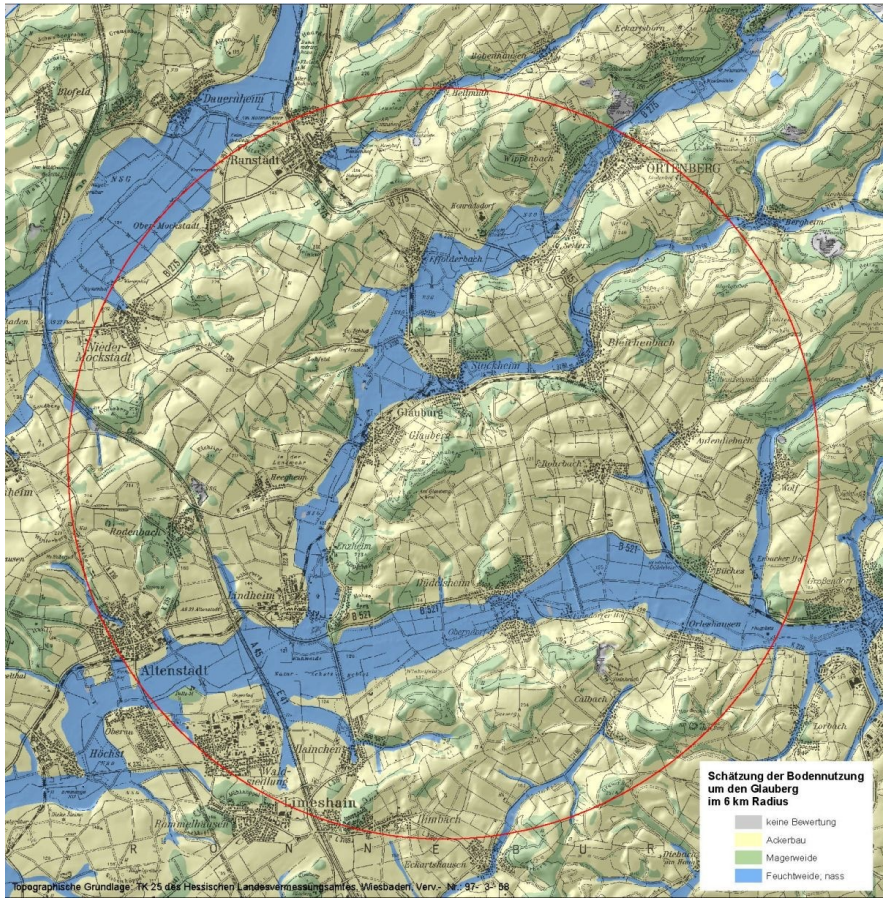
Photostitch,

Hand drawing,

AutoCAD

Final elevation

http://lykaionexcavation.org



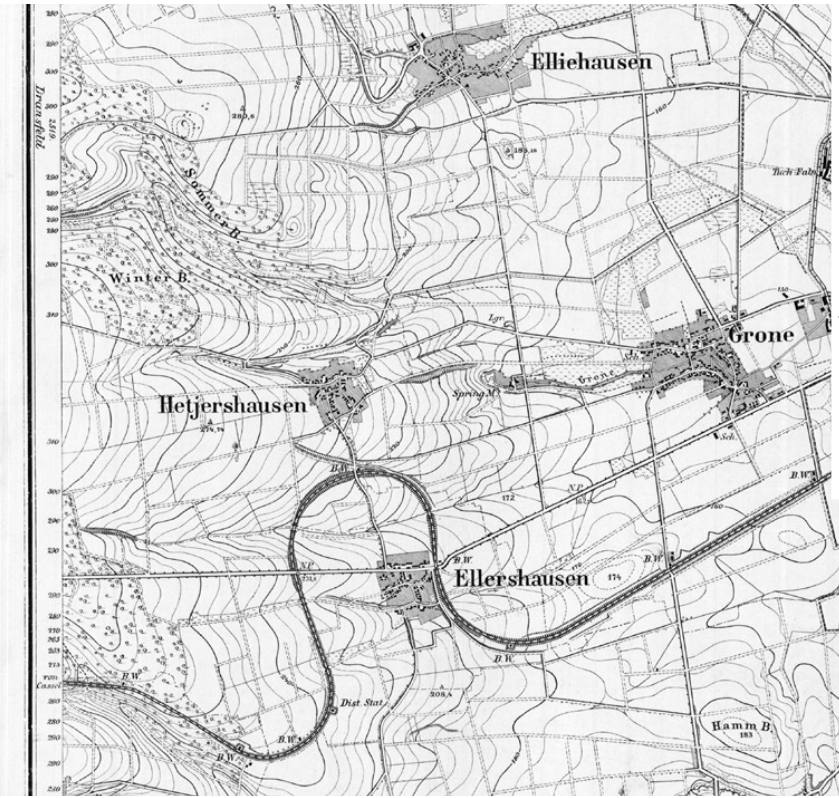
GEOARCHAEOLOGY

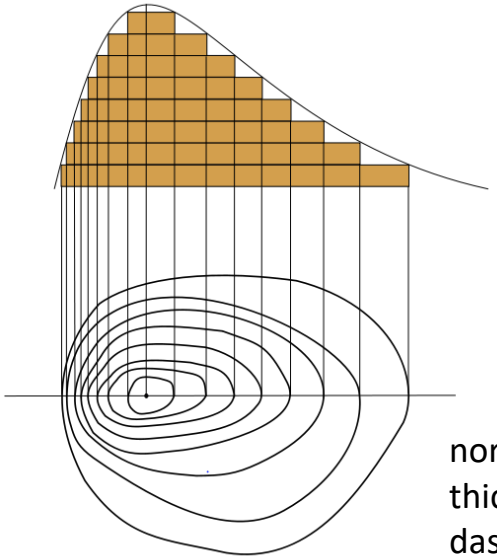
1. acquisition, storage and analysis of geodata with geoinformation systems (GIS)

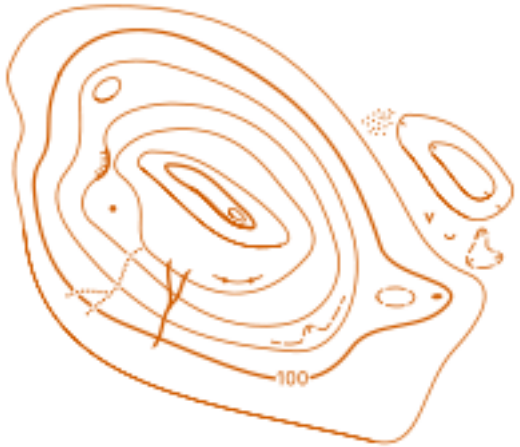
2. geovisualisation of historical spaces

http://www.fuerstensitze.de/1180_Laufende-Arbeiten-7730.html

CONTOUR LINE PROJECTION





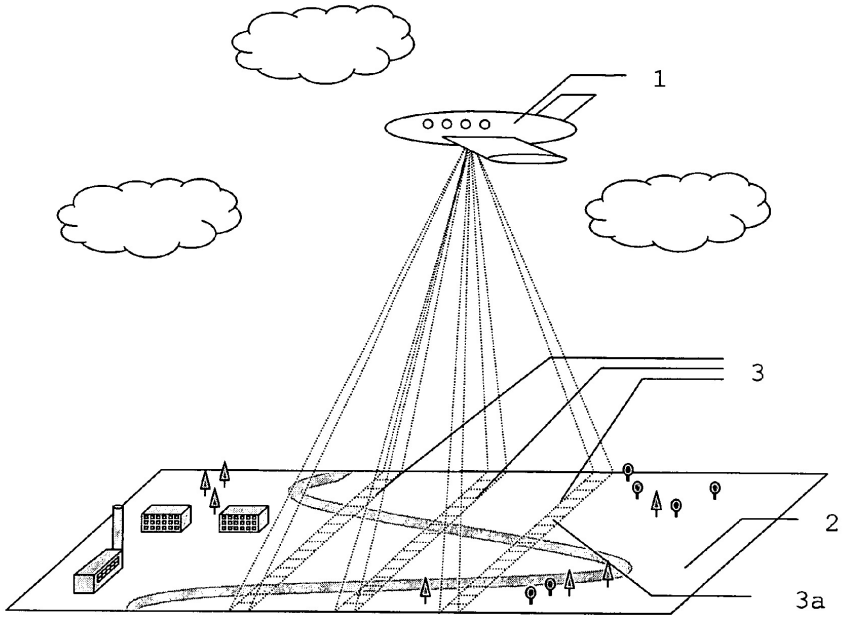


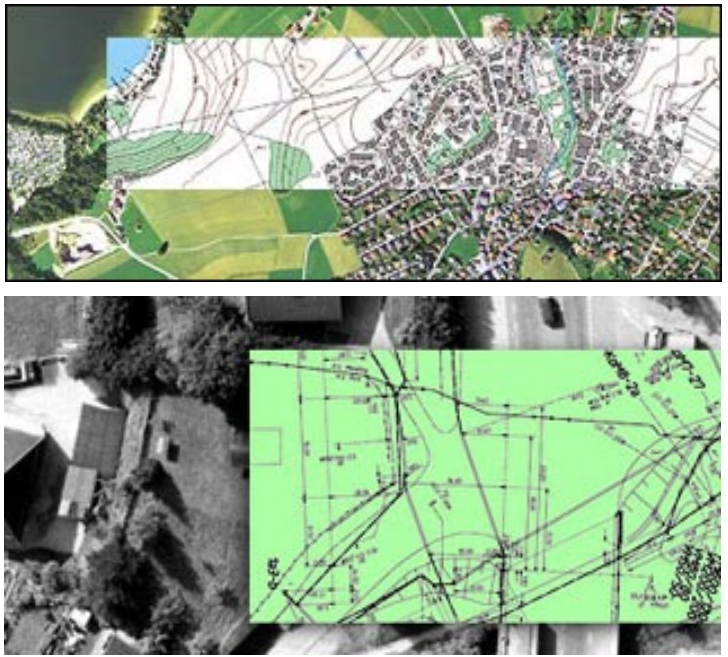
normal lines = main height lines
thick lines = counting lines
dashed lines = auxiliary contour lines

https://dewiki.de/Lexikon/Höhenlinie

Topographic Map of Göttingen from 1904
www.landesarchiv-nrw.de

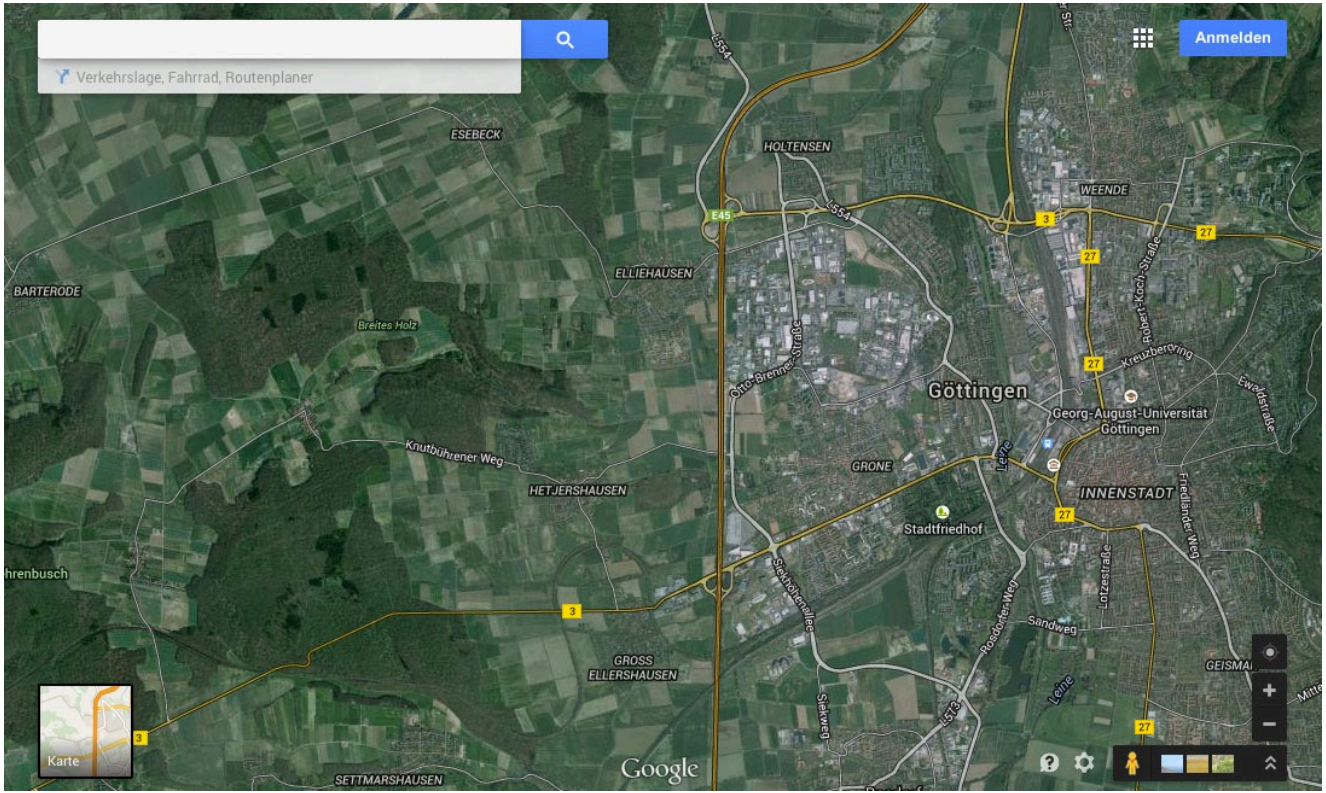
PHOTOGRAMMETRIC CREATION OF CONTOUR LINES





Geodata portals of the Federal Republic and the federal states for free downloading: http://www.digital-geography.com/geodaten-deutschland-datenquellen-im-ueberblick/#.VLy15FrDS6Y

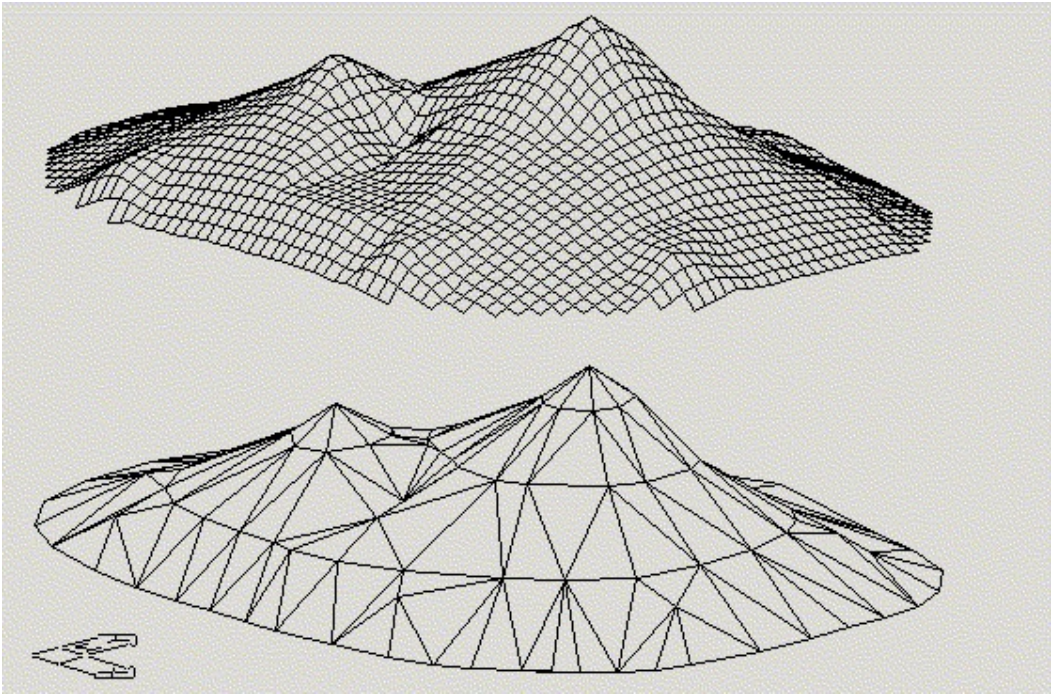
MULTIRESOLUTION ON THE FLOW



https://www.google.de/maps/@51.5276796,9.9221504,30876m/data=!3m1!1e3

DIGITAL TERRAIN MODEL

Exaggeration of the 3D representation through vertical stretching of the underlying coordinate system

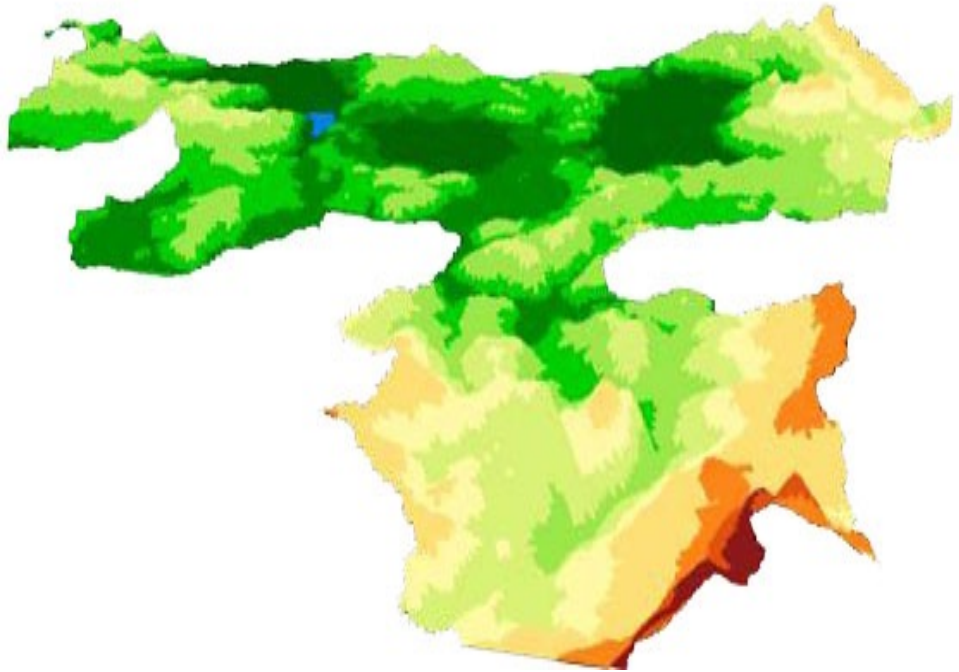


Representation of the relief as a digital terrain model based on triangulated irregular networks (TINs).

PROJECTION OF INFORMATION ONTO THE RELIEF

by colouring or texturing the relief

Hypsometric colouring: colour assignment as a function of terrain height

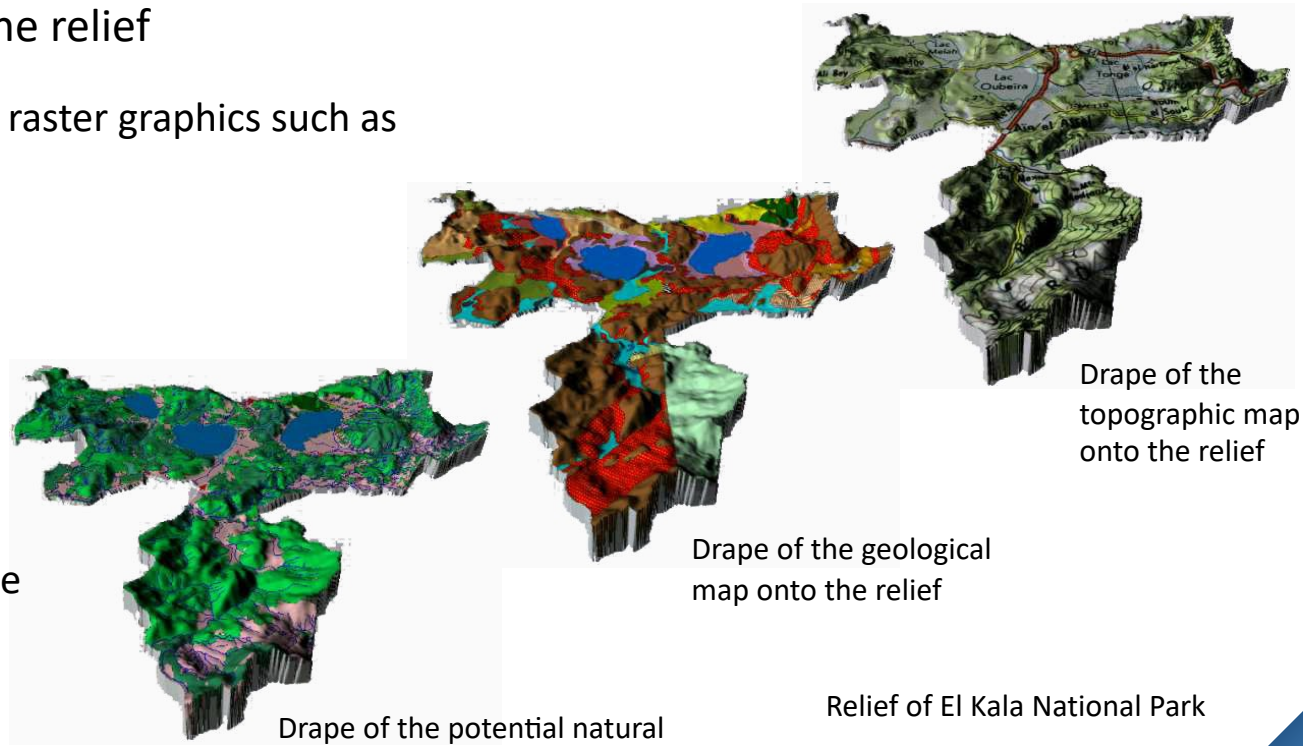


Relief of El Kala National Park in Algeria

PROJECTION OF INFORMATION ONTO THE RELIEF

by colouring or texturing the relief

"Image Drape": Texturing with raster graphics such as
scanned topographic maps,
aerial photographs or
satellite images



Drape of the topographic map onto the relief

Drape of the geological map onto the relief

Drape of the potential natural vegetation map on the relief

Relief of El Kala National Park

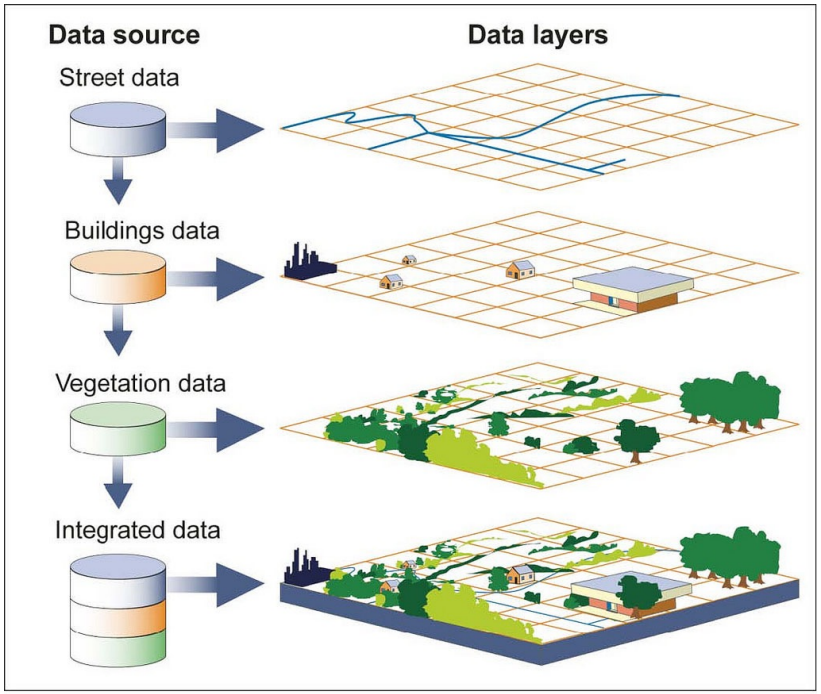
- requires georeferencing of the image data
- must be projected onto the relief parallel to the xy-plane.

PROJECTION OF INFORMATION ONTO THE RELIEF

by colouring or texturing the relief.

Multi-texturing techniques to display thematic information:

- Combination of several texture layers
- Visual simulation of unevenness in the terrain with simplified relief representation ("bump mapping")



https://media.nationalgeographic.org/assets/photos/000/322/32282.jpg

POSITIONING OF VECTOR GEOOBJECTS

by colouring or texturing the relief

- Buildings, pylons, bridges, tunnels, dams, wind turbines, plants or drill profiles

- Symbols

- linear objects such as streets, land and property boundaries or building ground plans

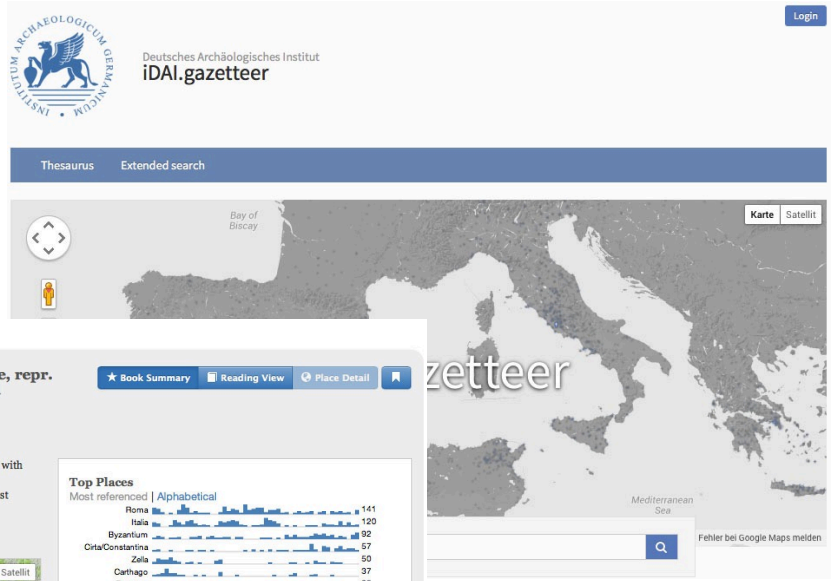
www.romereborn.org

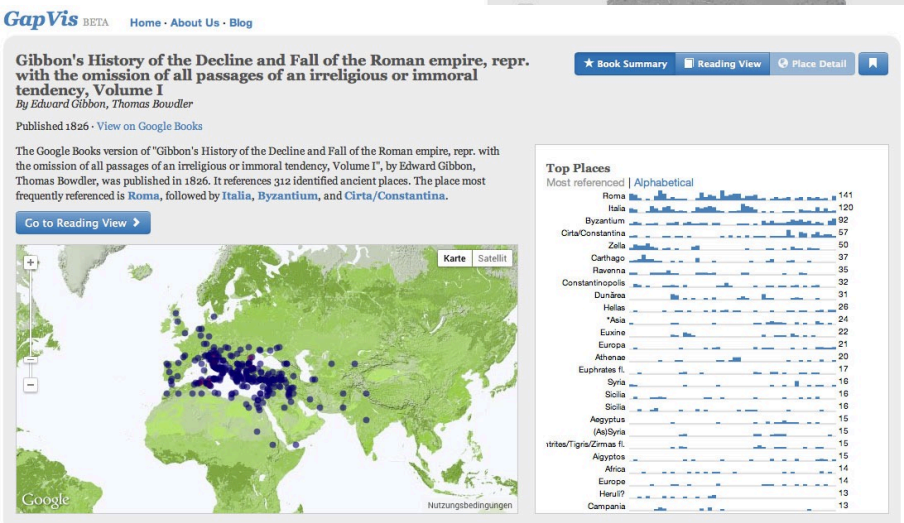
ROME REBORN

http://romereborn.frischerconsulting.com
http://www.gearthblog.com/blog/archives/2008/11/ancient_rome_in_3d_for_google_earth.html

Tools for visualising data on a map:

http://geobrowser.de.dariah.eu
http://openlayers.org/
http://www.simile-widgets.org/timeline/
http://gazetteer.dainst.org
http://nrabinowitz.github.io/gapvis/
s.a. http://gapvis.hellespont.dainst.org
http://orbis.stanford.edu
http://neatline.org



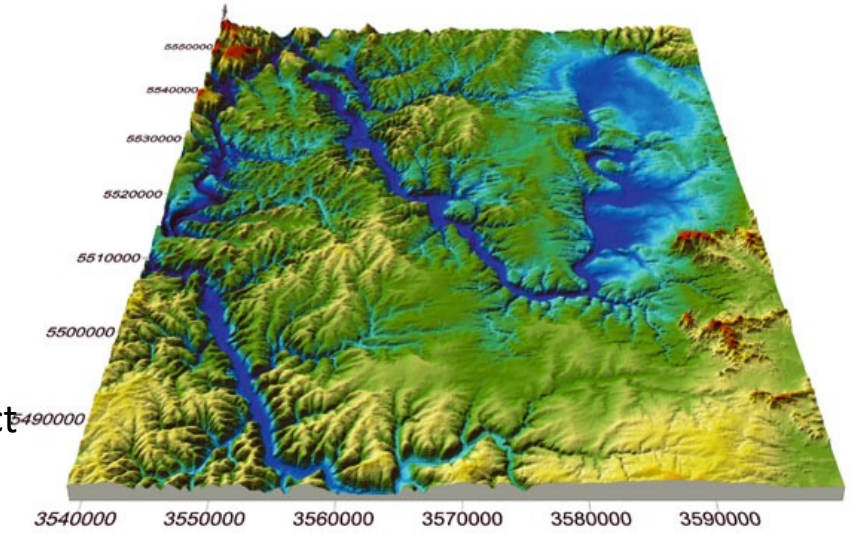


BENEFITS OF DIGITAL GEOVISUALISATION

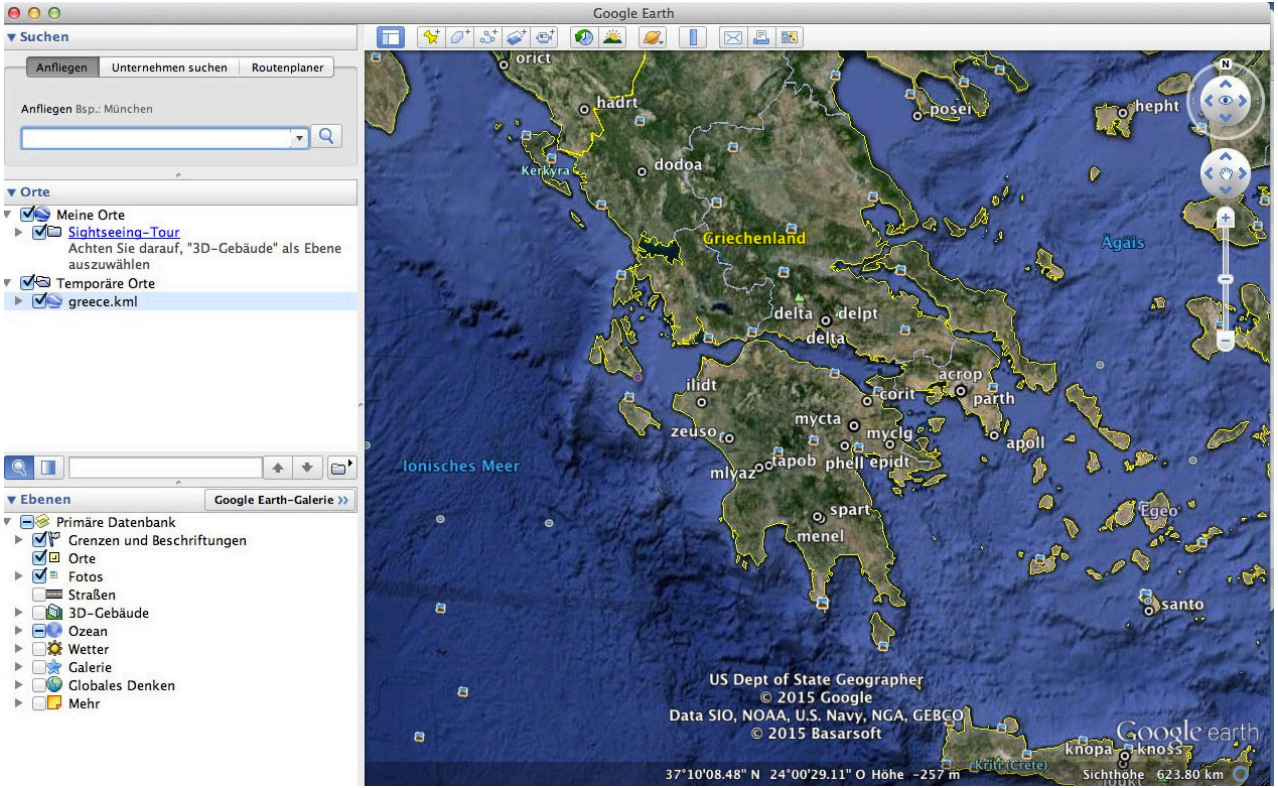
1. Three-dimensional representation space
2. georeferenced representation
3. representation of the earth's surface ("relief", "3D topography", "terrain" or "terrain model")
4. consideration of thematic information, e.g.

- Insertion of text
- Cartographic conversion into colours and symbols
- GIS connection (reading geoobjects, writing back edited geometries and/or thematic attributes, calling up GIS analysis methods, etc.)
- Varying spaces
- varying degrees of abstraction (photorealism vs. abstract representation)

http://www.fuerstensitze.de

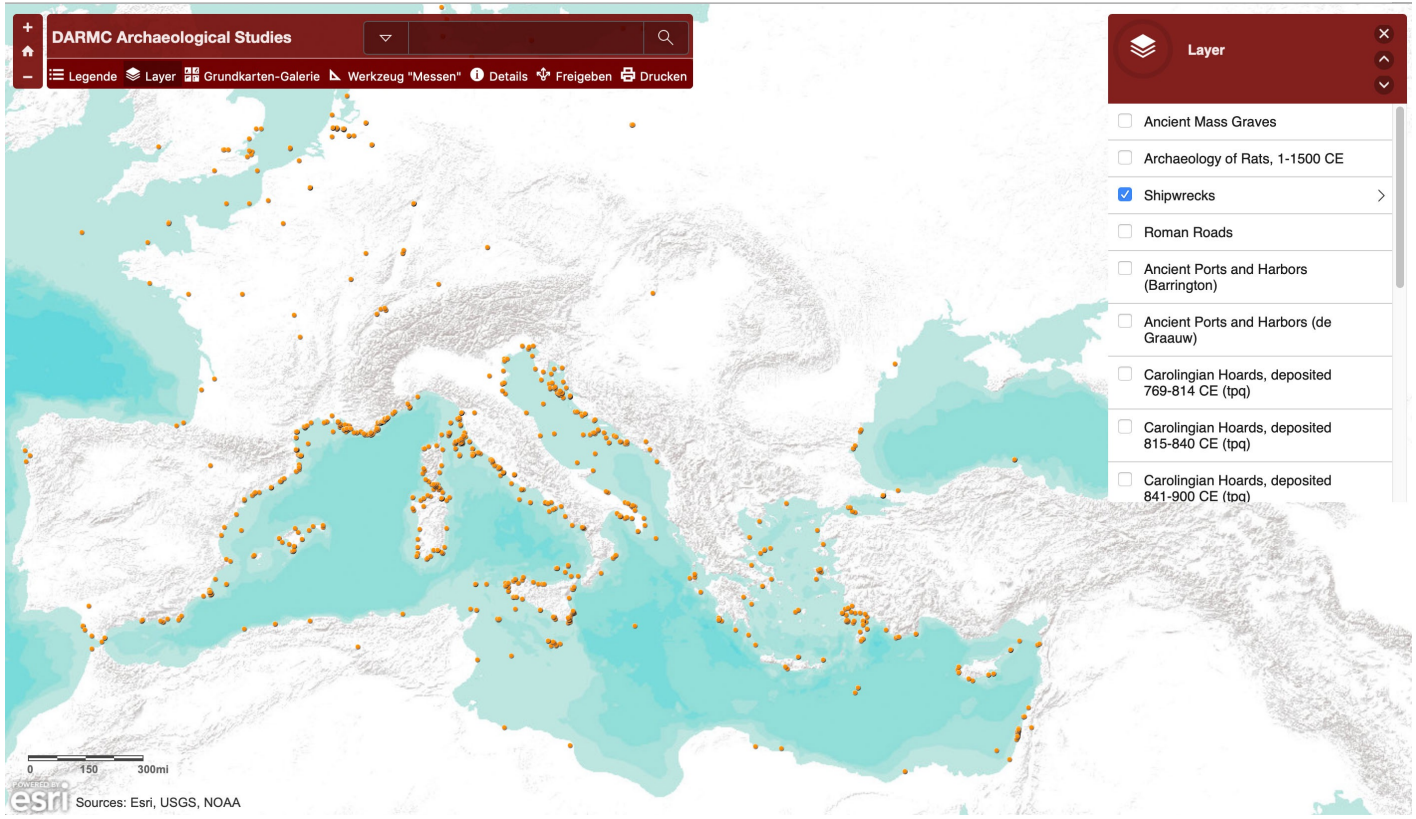


GOOGLE EARTH



https://earth.google.de

DIGITAL ATLAS OF ROMAN AND MEDIEVAL CIVILIZATION



https://darmc.harvard.edu

ARCHES. HERITAGE INVENTORY & MANAGEMENT SYSTEM

http://archesproject.org

GEOARCHAEOLOGY

Research in the field of settlement archaeology or landscape archaeology to reconstruct historical landscapes using scientific methods of geography (e.g. geomorphology, soil geography and settlement geography) and geology (e.g. sediment investigation and raw material analyses).

Geoscientific methods:

- Analysis of Holocene sediments (colluvia, alluvial clays, lake sediments and marine sediments).
- pollen analysis
- geophysical investigations, such as geoelectrics and georadar
- Determination of the origin of rocks (thin section, geochemical analyses).

Objectives: Acquisition and analysis

- topographical changes, such as the flooding of valleys or the silting up of lakes

of utilisation potentials of the ancient population (man-environment relationship)

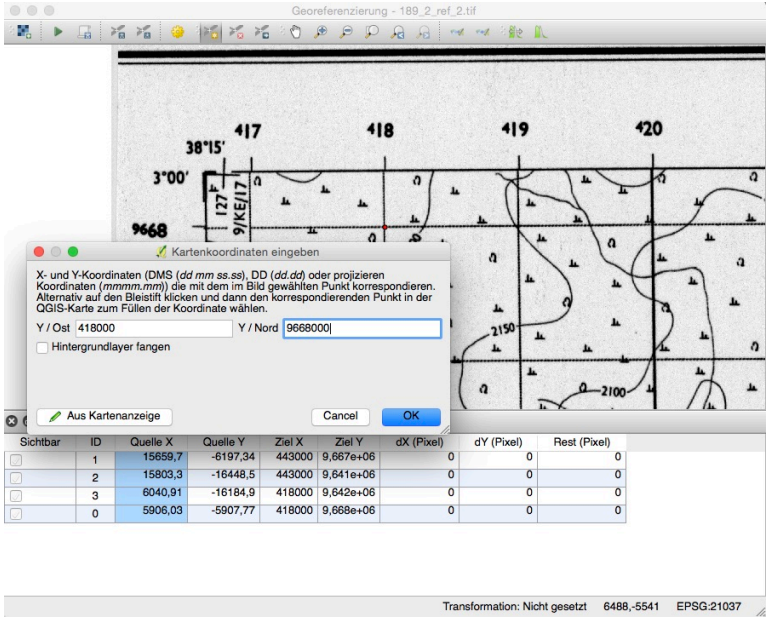
GEOINFORMATION SYSTEM (GIS)

- Data acquisition in the field with GPS devices
- Digitisation of paper maps and survey plans
- On-screen digitisation of satellite and aerial photographs
- Mapping of sources

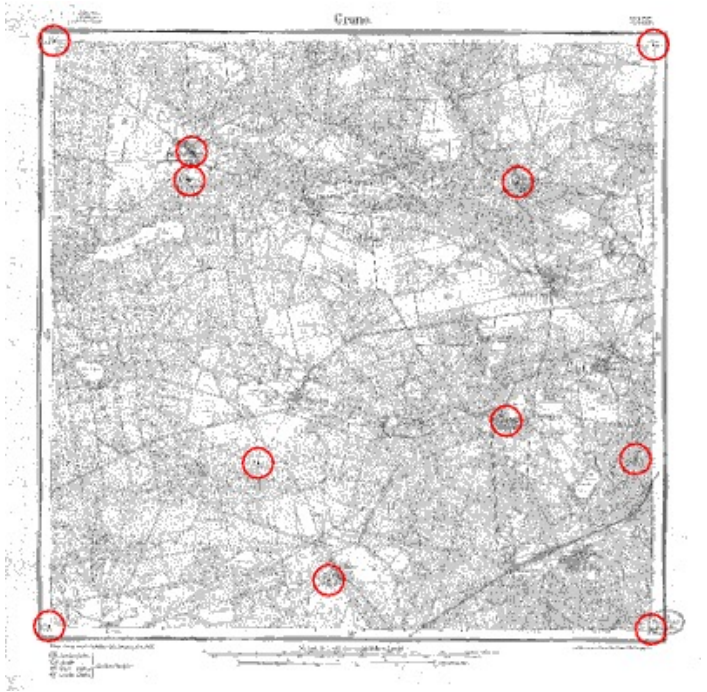
extensive list of archaeological GIS, especially in Italy:
https://www.aarome.org/research/resources/maps-gis

GEOREFERENCING (RECTIFY MAPS)

Digitisation of paper maps and survey plans using georeferencing methods

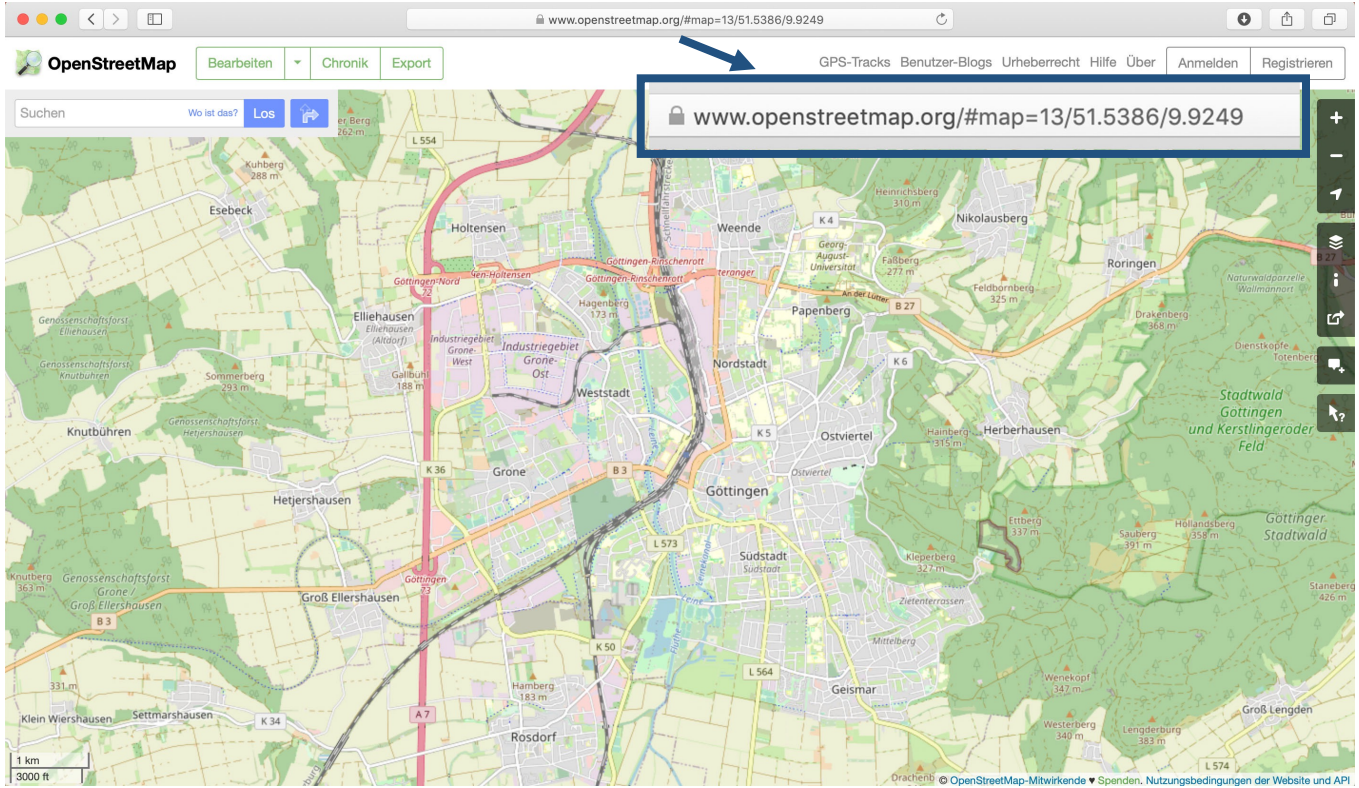


Georeferencing function in QGIS

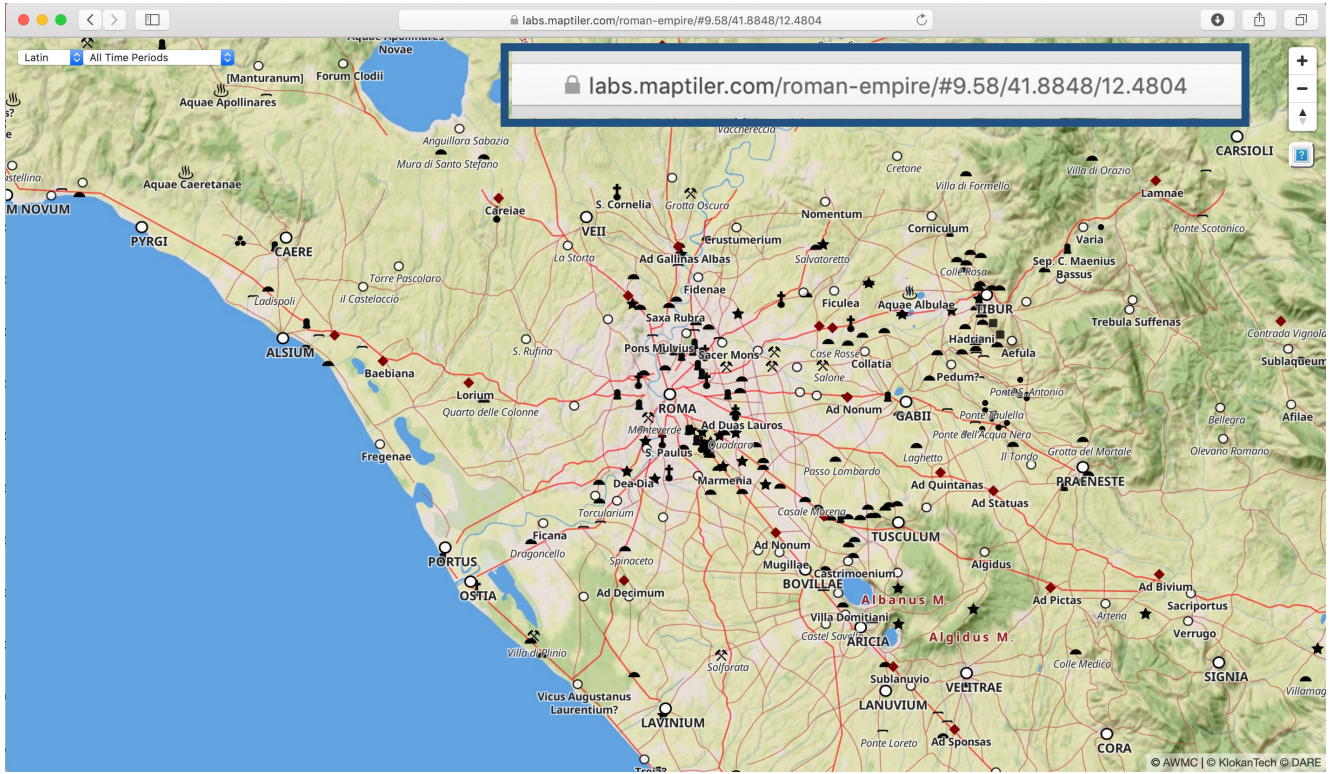


Control points for a sheet of the Preußische Landesaufnahme of 1880 (https://www.oebvi-schroeder.de/leistungen/hist_preuss.html)

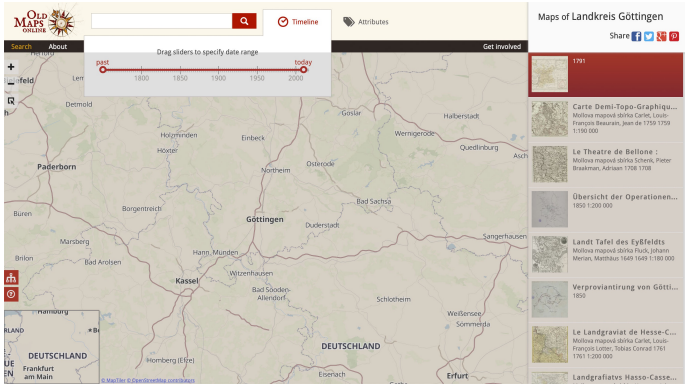
GEOREFERENCING (OpenStreetMap)



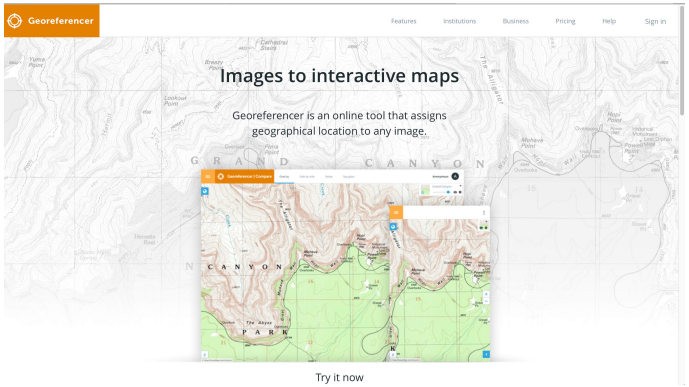
GEOREFERENCING (Digital Atlas of the Roman Empire)



https://dh.gu.se/dare/

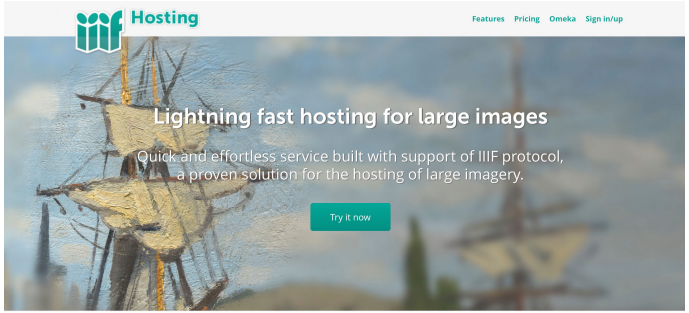


www.oldmapsonline.org



www.georeferencer.com

http://recogito.pelagios.org



www.iiifhosting.com

GEOINFORMATION SYSTEM (GIS)

A GIS is a type of database management system that links each data element to a coordinate-based representation of its location (e.g. as a point, line, polygon or pixel). It offers a wide range of possibilities as a "Historical GIS":

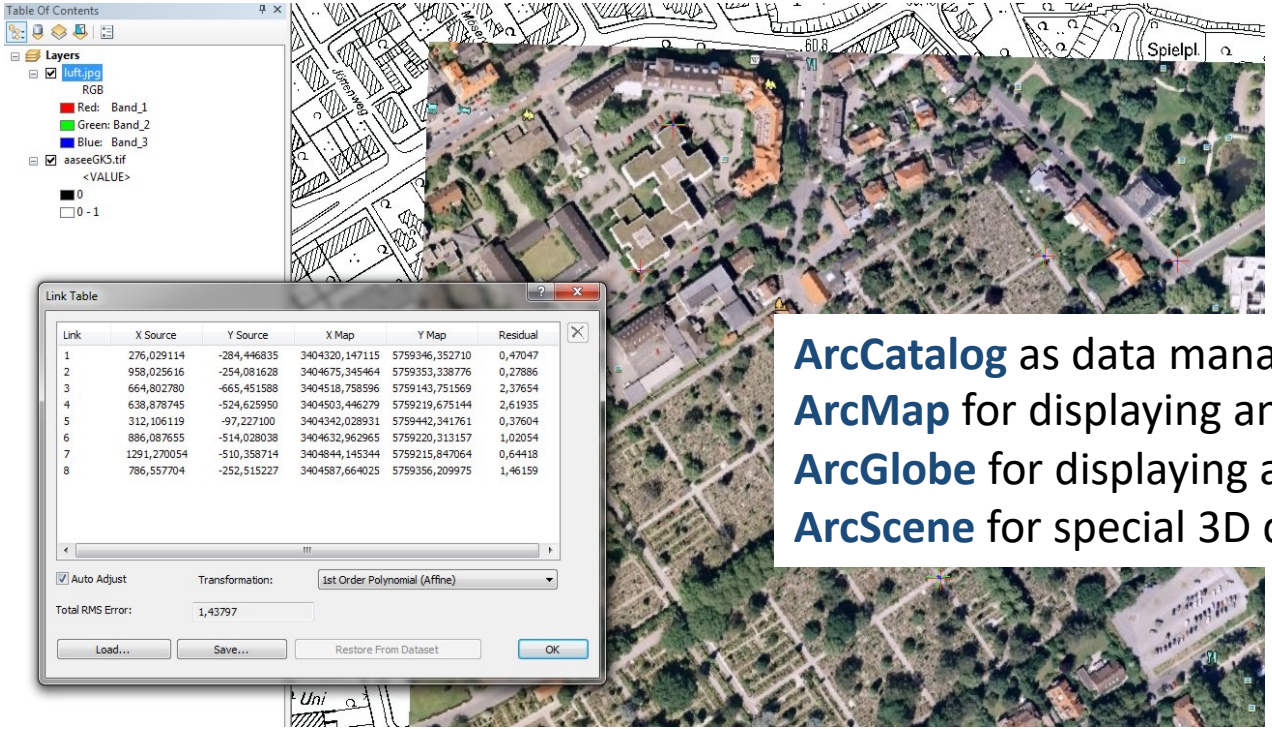
- Geodata technologies
- Analytical methods
- Rectification of old maps
- Display and analysis of information located anywhere on earth
- Visualisation of information in a geographic / geopolitical context
- Examination of this information at different scales. Adding data
- Finding, describing and explaining spatial patterns
- Ability to share the data
- Managing paradata (metadata in GIS)
- Access to sources, documentation of sources

ARCHAEOLOGICAL INFORMATION SYSTEM (AIS): REQUIREMENTS

- What information is digitally acquired?
- Which programmes/applications are used for the acquisition?
- Which standards are taken into account or aimed at?
- In what form is the data acquired (types, structures, standards, formats, ...)? How are geodata acquired? With CAD? With GIS? (Functionality, costs, ...)
- What role do laser scans and SfM play in 3D acquisition? Which methods, programmes and data formats are used for this?
- How are the collected data integrated into existing information systems?
- How sustainable are these data? How long can they be used? And how can long-term or permanent usability or archivability be achieved?
- What role does free and open source software play in these contexts?

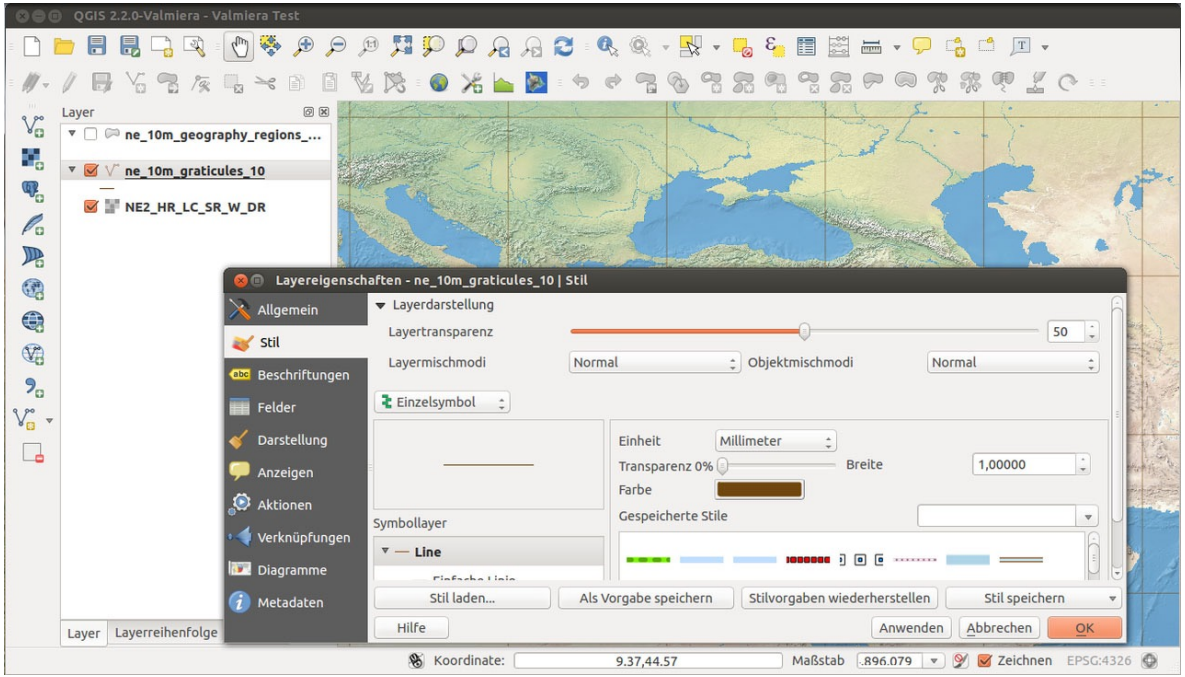
Empfehlungen der Kommission "Archäologie und Informationssysteme" des Verbands der Landesarchäologen:
http://www.landesarchaeologen.de/verband/kommissionen/archaeologie-und-informationssysteme/

ArcGIS: www.arcgis.com



ArcCatalog as data management unit
ArcMap for displaying and designing 2D maps
ArcGlobe for displaying and designing 3D globes
ArcScene for special 3D display and analysis

QGIS (früher QuantumGIS): http://qgis.org

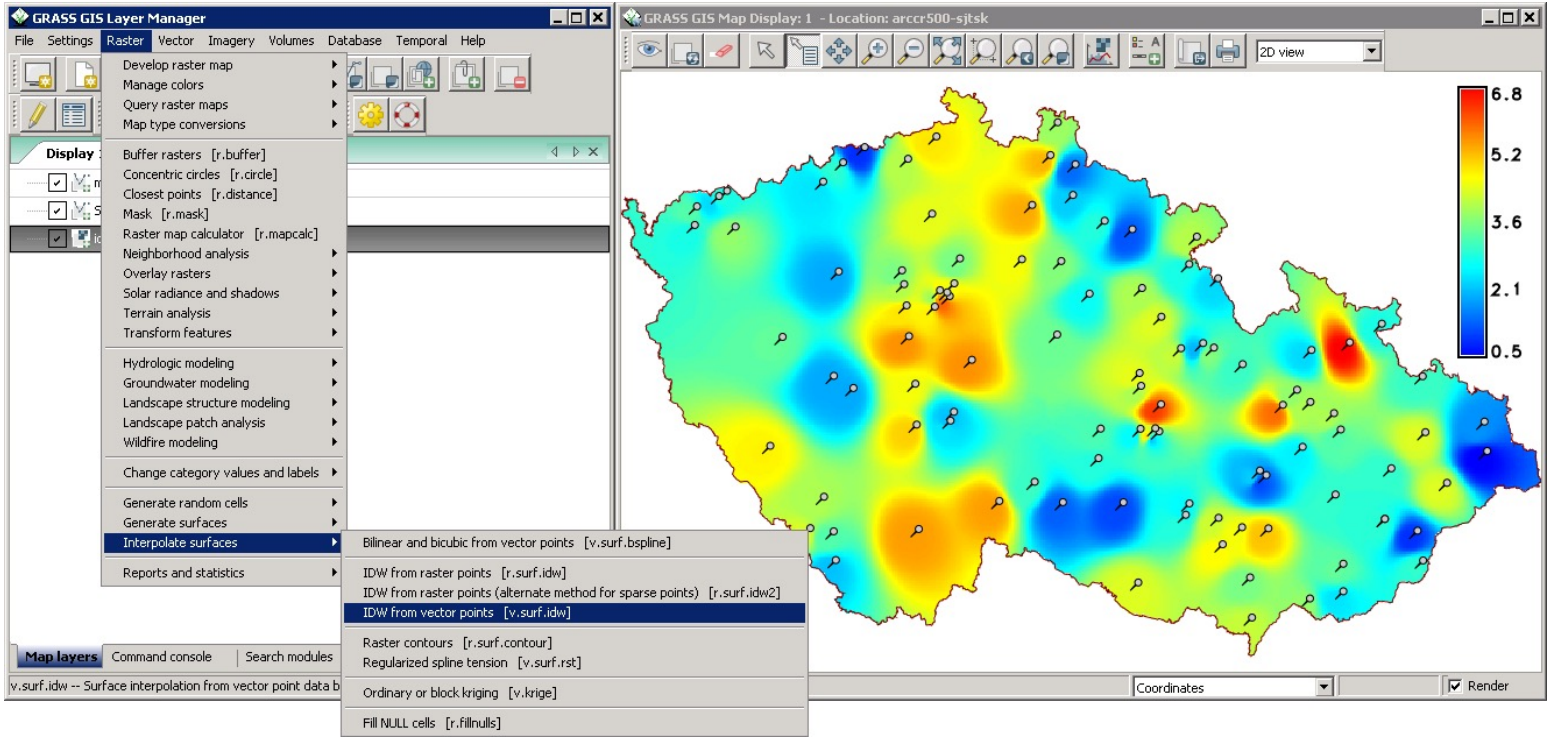


Tutorials: www.digital-geography.com/

Armin Volkmann, Archäologische Fundkartierung und Zeichnungs-Georeferenzierung mit QGIS. HeiDOK Heidelberger Dokumentenserver (2015), http://www.ub.uni-heidelberg.de/archiv/19929

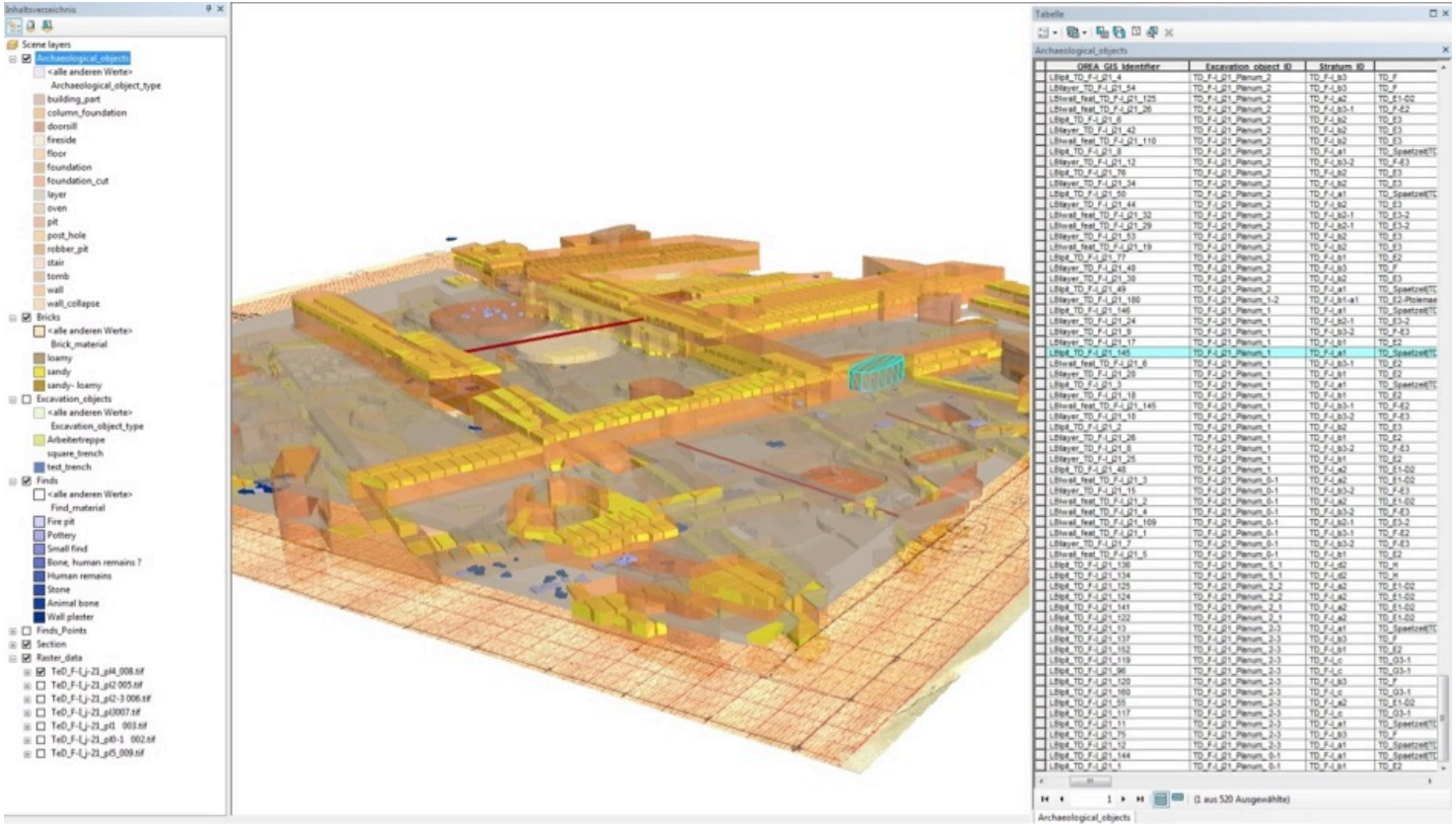
Armin Volkmann, Tutorial Georeferencing of historical maps with QGIS. Georeferenzierung von historischen Karten mit QGIS – Ein Bilderbuch (2014), http://archdigi.hypotheses.org/420

GRASS GIS: http://grass.itc.it



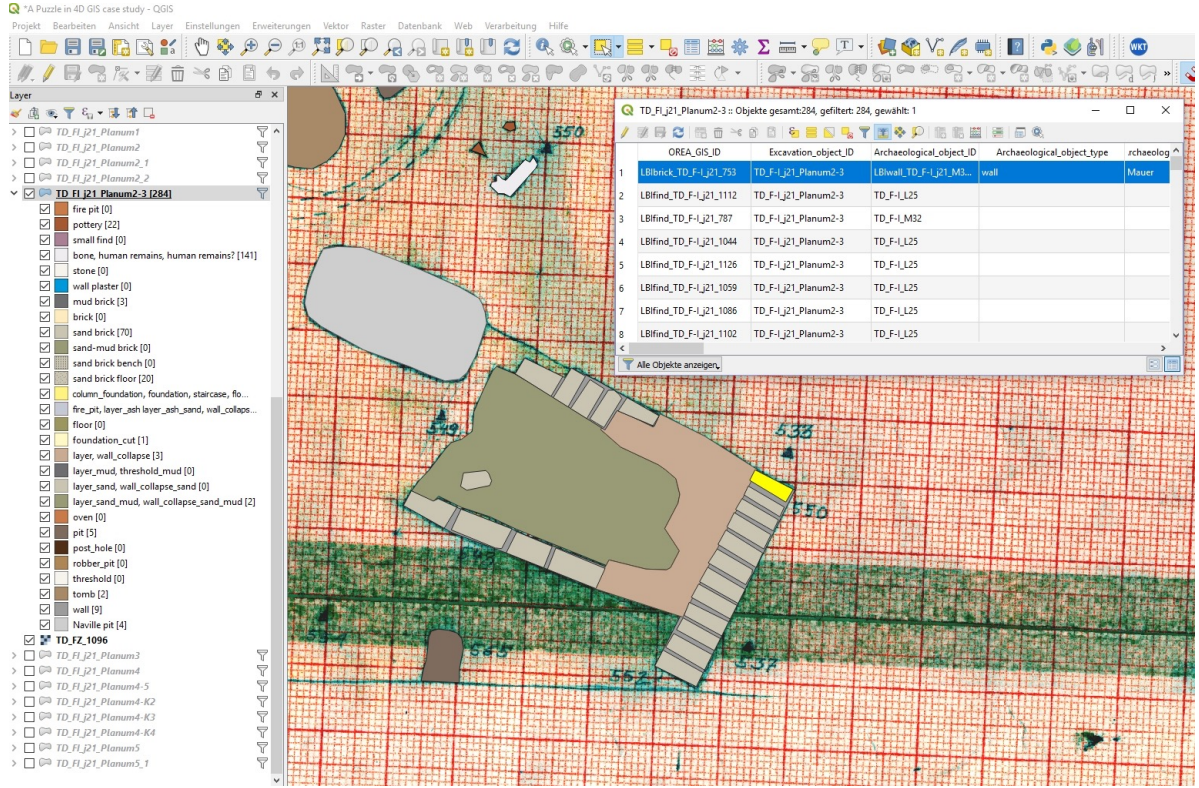
Tutorials: http://grassgistutorials.com

TELL EL-DABA ARCHAEOLOGICAL INFORMATION SYSTEM



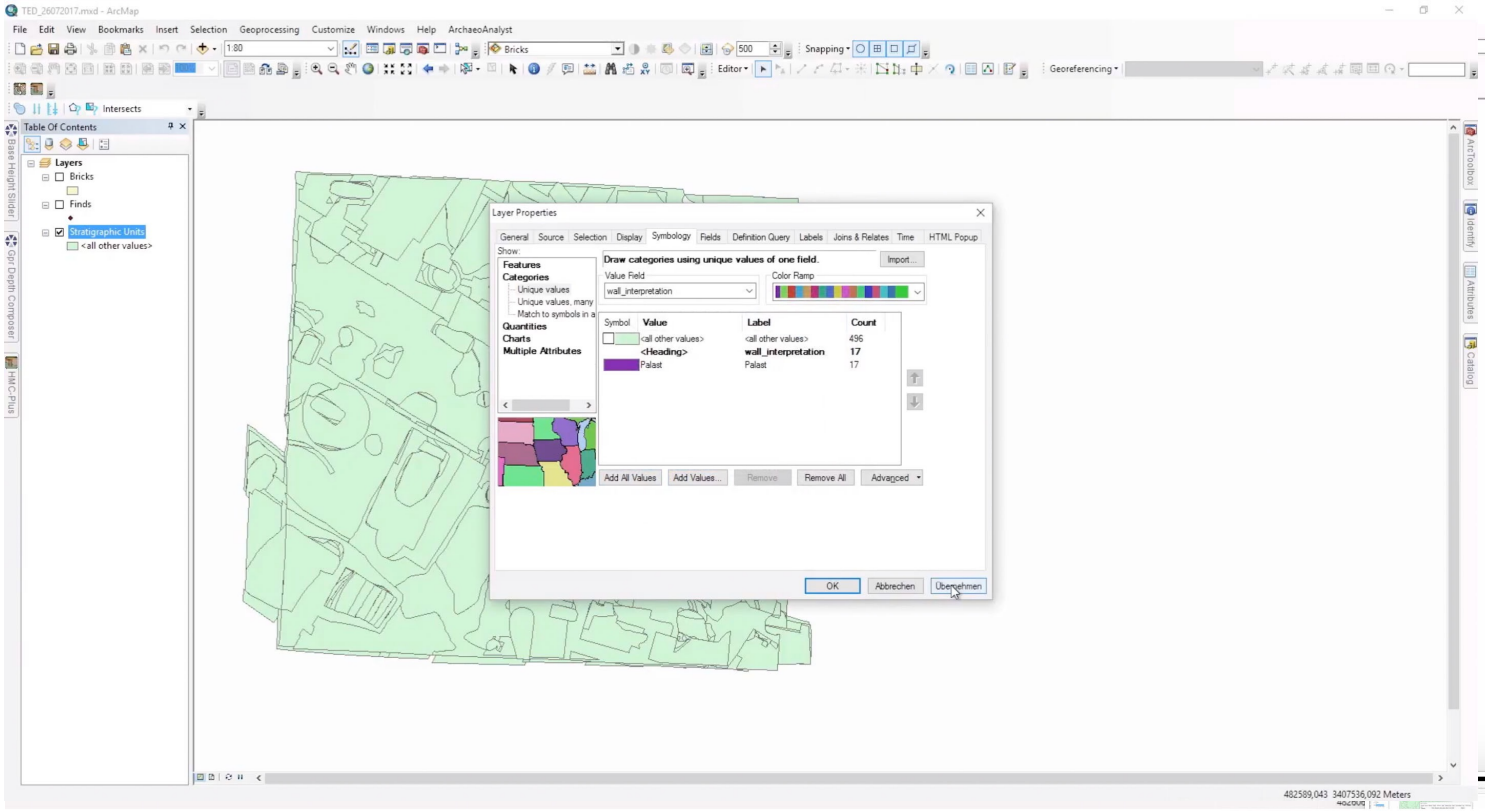
https://4dpuzzle.orea.oeaw.ac.at/ais/

TELL EL-DABA ARCHAEOLOGICAL INFORMATION SYSTEM



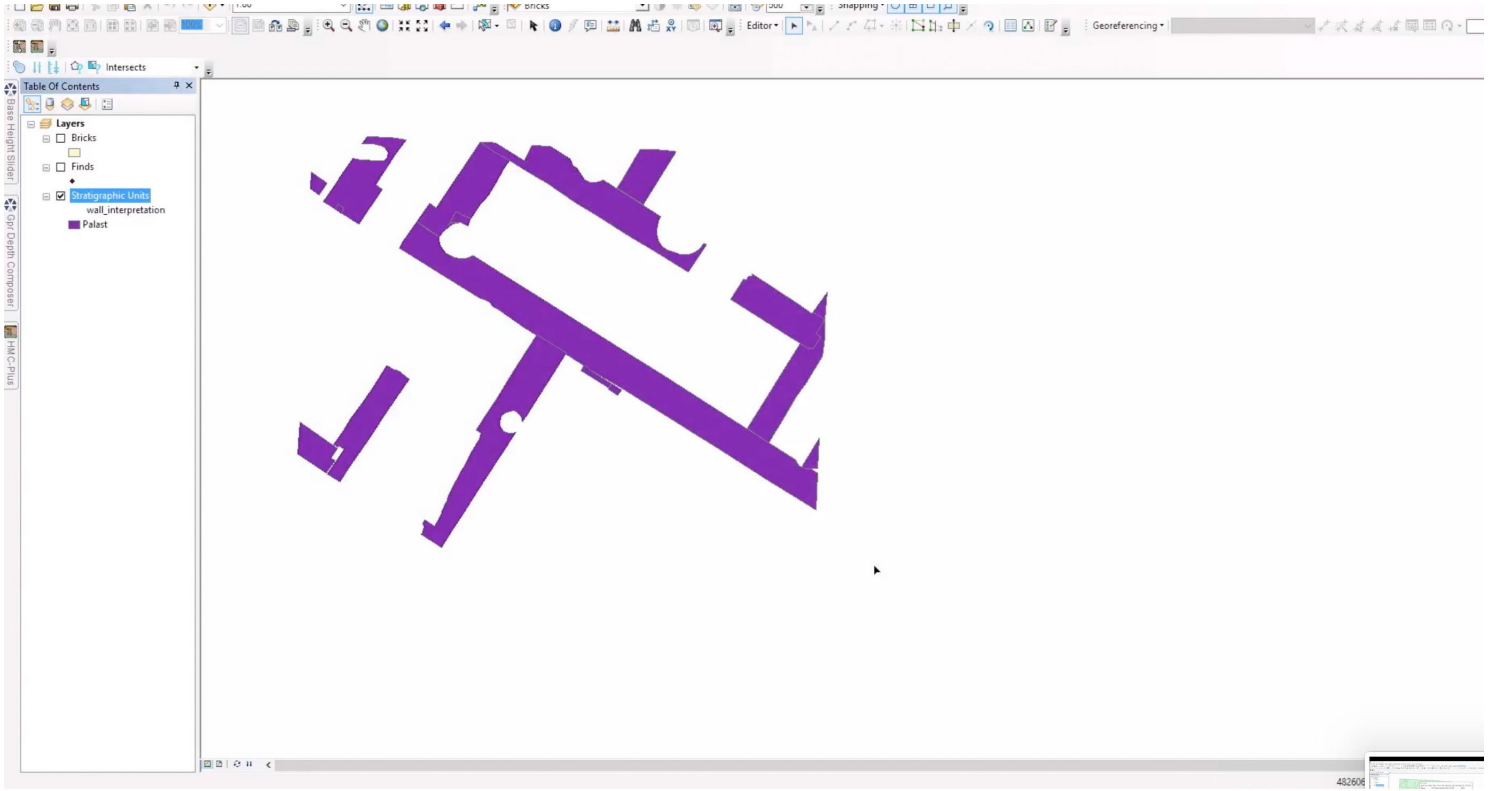
https://4dpuzzle.orea.oeaw.ac.at/ais/

TELL EL-DABA ARCHAEOLOGICAL INFORMATION SYSTEM



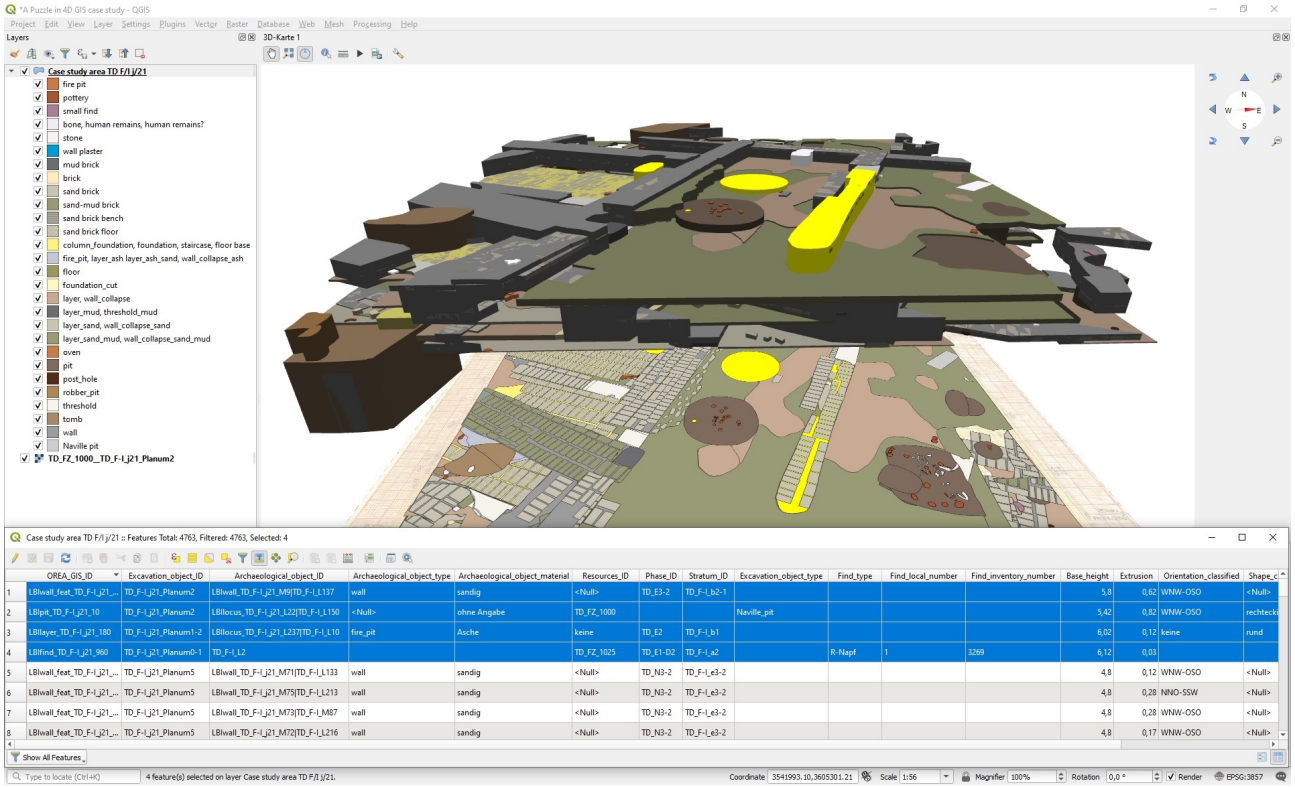
https://youtu.be/rEqhDihwe9U

TELL EL-DABA ARCHAEOLOGICAL INFORMATION SYSTEM



https://youtu.be/rEqhDihwe9U

TELL EL-DABA ARCHAEOLOGICAL INFORMATION SYSTEM



https://4dpuzzle.orea.oeaw.ac.at/ais/

INFRASTRUCTURE FOR SPATIAL INFORMATION IN EUROPE (INSPIRE)

is the project for a common spatial data infrastructure in Europe. The European Union wants to use it to support joint environmental policy decisions.

https://inspire.ec.europa.eu
https://www.geoportal.de/DE/GDI-DE/INSPIRE/inspire.html?lang=de

TIMEMACHINE EUROPE

Time Machine

ABOUT US NEWSROOM LOCAL TIME MACHINES PROJECT SCOUTING SERVICE MEDIA JOIN US

Amsterdam

Beginning its journey in 2017 and covering the years 1500-2000 AD, the Amsterdam Time Machine pushes the boundaries of science and technology to build a model of this historical city's past.

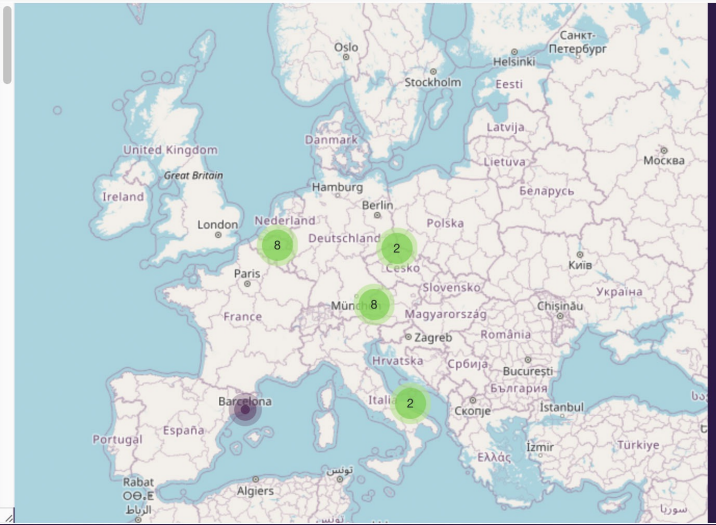
Antwerp

Beginning its journey in 2012 and covering the years 1500-2000 AD, the Antwerp Time Machine pushes the boundaries of science and technology to build a model of this historical city's past.

Barcelona

The Barcelona Time Machine pushes the boundaries of science and technology to build a model of this historical city's past.

Broumov



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 820323.

CONTACT
NEWSLETTER
SERVICE

FACTSHEET
MANIFESTO
PRESS MATERIAL

www.timemachine.eu

DATING PROBLEMS

DATE FORMATS

B.C.	A.D.
B.C.E. (before Christian / common era)	AD
B.C. (before Christ / the turn of time)	A.D. (Anno Domini / our calendar, turn of the century)
BC	
BCE	CE (common era)
av. J.C.	ap. J.C.
aC or AC	dC or DC

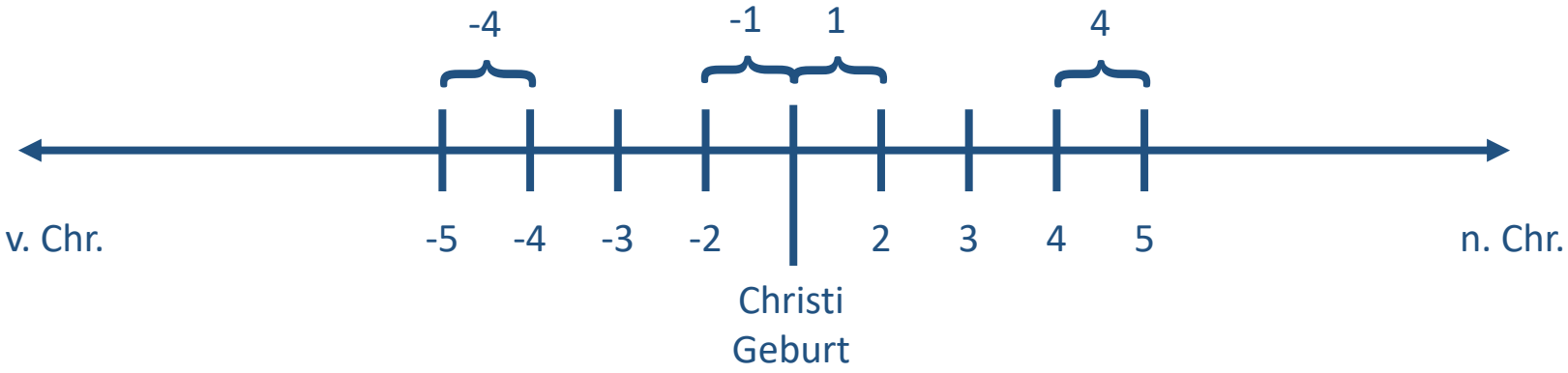
The monk Dionysius Exiguus (ca. 470-556 AD) founded a chronological system that takes the year of the Incarnation of the Lord (anni incarnationis Domini) as its starting point.

He sets the first year with the birth of Christ on the first day of the year 1 (1.1.1).

There is no year 0!

The system only became established in the Middle Ages. The writings of Beda Venerabilis (d. 735 AD) are important.

DATE FORMATS



OLYMPIADS

Sporting and musical competitions held every four years in Olympia.

The Olympiad is the period of four years.

776 BC = Ol. 1, 1

775 BC = Ol. 1, 2

774 BC = Ol. 1, 3

773 BC = Ol. 1, 4

772 BC = Ol. 2, 1

etc.

SYNCHRONISATION OF THE TIME CALCULATIONS

That the calculation and fixing of the 1st Olympiad in the year 776 is correct can be deduced from other chronological data. The Greek author Diodor 20,5,5 reports of a solar eclipse in the 117th Olympiad in the third year, which can be astronomically calculated with modern methods to 15 August 310 BC. If we now calculate backwards, we arrive at the year 776 with the first Olympiad.

SIGNIFICANCE OF THE OLYMPIAD ACCOUNTS

The Roman author Pliny the Elder, who died during the eruption of Vesuvius in 79 AD, gives the Akmé dates (flowering) of the artists in Olympiads in his Natural History.

Pliny (NH 34, 49-52): Hereupon art ended, but revived in the 156th Olympiad (= 156-153 B.C.) with the artists who, although far below those previously mentioned, were nevertheless esteemed. [...]

Cessavit deinde ars ac rursus olympiade CLVI. revixit, cum fuere longe quidem infra praedictos, probati tamen [...]

COMPETING SYSTEMS

Eponyma count: Naming officials or priests

- Athens: Archons
- Sparta: Ephors
- Rome: consuls, Roman imperial titulatures

Example: The historian Hellanikos of Mytilene based his history on the list of priestesses of the Goddess Hera from Argos.

ab urbe condita = foundation of Rome in 753 BC.

Beginning of Roman tradition in the 3rd century BC: Naevius, Q. Ennius, Fabius Pictor

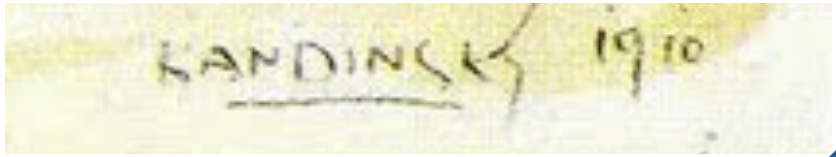
There is a time gap between the beginning of a historical tradition and the date of the foundation of Rome > Problem of transmission

Historical date is a construction (e.g. M. Terentius Varro 115-27 B.C.)

SOURCE CRITICISM

Sometimes artists pre-date their works, sometimes dates are falsified

https://artsandculture.google.com/asset/composition-vii/CQHOKgpWcL_UPA



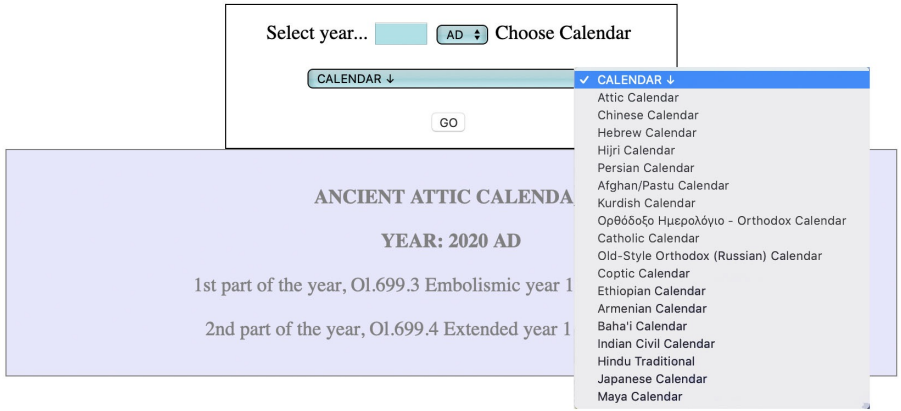
ABSOLUTE CHRONOLOGY

Dating by naming the supervising officials (archons).

Archons are officials about whom we have particularly good information for Athens. There, 9 archons originally formed the college of the highest state officials. One could only be elected archon once in a lifetime. The beginning of the establishment of the one-year archontate was given in later sources as 683/2 BC. From the end of the 5th century at the latest, it was customary to name the year after the highest official, the archon eponymos.

Panathenean Prize Amphora 323/2 BC

Document relief of 405/4 and 403/2 BC. (Athens, Acr.Mus. 1333)



January

WEDNESDAY	THURSDAY	FRIDAY	SATURDAY	SUNDAY	MONDAY	TUESDAY
[1/1/2020 O.S:19/12/2019] 7 of Poseideon II, Ol.699.3	[2/1/2020 O.S:20/12/2019] 8 of Poseideon II, Ol.699.3	[3/1/2020 O.S:21/12/2019] 9 of Poseideon II, Ol.699.3	[4/1/2020 O.S:22/12/2019] 10 of Poseideon II, Ol.699.3	[5/1/2020 O.S:23/12/2019] 11 of Poseideon II, Ol.699.3	[6/1/2020 O.S:24/12/2019] 12 of Poseideon II, Ol.699.3	[7/1/2020 O.S:25/12/2019] 13 of Poseideon II, Ol.699.3
WEDNESDAY	**THURSDAY**	**FRIDAY**	**SATURDAY**	**SUNDAY**	**MONDAY**	**TUESDAY**
[8/1/2020 O.S:26/12/2019] 14 of Poseideon II, Ol.699.3	[9/1/2020 O.S:27/12/2019] 15 of Poseideon II, Ol.699.3	[10/1/2020 O.S:28/12/2019] 16 of Poseideon II, Ol.699.3	[11/1/2020 O.S:29/12/2019] 17 of Poseideon II, Ol.699.3	[12/1/2020 O.S:30/12/2019] 18 of Poseideon II, Ol.699.3	[13/1/2020 O.S:31/12/2019] 19 of Poseideon II, Ol.699.3	[14/1/2020 O.S:1/1/2020] 20 of Poseideon II, Ol.699.3

Tool for converting ancient calendars into the system used today: https://www.epistemeacademy.org/calendars/yearly_calendar.html

A. S. Samuel, *Greek and Roman Chronology. Calendars and Years in Classical Antiquity* (München: Beck, 1972)

ABSOLUTE CHRONOLOGY

Dating by naming the supervising officials (archons)

447/46 - 433/32 BC; dating via the naming of the eponymous archon in the construction accounts of the Parthenon in Athens.

Inscriptiones Graecae I³ Nr. 436-451: construction accounts of the Parthenon

R. Meiggs - D. Lewis (Hrsg.), A Selection of Greek Historical Inscriptions (1989) 162-165 Nr. 59

K. Brodersen u.a. (Hrsg.), Historische griechische Inschriften in Übersetzung I1 (1992) 67 Nr. 94

B. Wesenberg, Parthenosgold für den Parthenonbau?, AA 1985, 49-53

ROMAN EMPERORS

The chronological framework for counting the reigning years of the Roman emperors is formed by the *tribunicia potestas* (tribunician power).

Dietmar Kienast, *Römische Kaisertabelle. Grundzüge einer römischen Kaiserchronologie* (Darmstadt: WBG, 1990)

cos. I	1. Jan.–30. April 91
cos. II	1. Jan.–Juni 98
cos. II design. III	seit Okt. 98 (?)
cos. III	1. Jan.–28. Febr. (?) 100
cos. III design. IV	seit Okt. 100
cos. IV	1. Jan.–Ende März 101
cos. IV design V	seit Okt. 102
cos. V	1. Jan.–13. Jan. 103
cos. V design. VI	seit Okt. 111
cos. VI	1.–13. Jan. (?) 112
trib. pot. I	28. Okt. 97–9. Dez. 97
trib. pot. II	10. Dez. 97–9. Dez. 98
trib. pot. III	10. Dez. 98–9. Dez. 99
trib. pot. IV	10. Dez. 99–9. Dez. 100
trib. pot. XXI	10. Dez. 116–7. (?) Aug. 117
imperator II	Herbst 101
imp. III	Frühjahr 102
imp. IV	Herbst (vor 19. Nov.) 102
imp. V	Juli (oder Aug.) 106
imp. VI	Aug. (oder Herbst) 106
imp. VII	Sept. (?) 114
imp. VIII	Okt./Nov. (?) 114 (?)
imp. IX–XI	115
imp. XII–XIII	116 (vor 8. Sept.)
Germanicus	Nov. 97
Dacicus	Herbst 102
Parthicus	20. oder 21. Febr. 116 (FOst)
Optimus	zwischen 10. Aug. und 1. Sept. 114

Offices and titles of the Emperor Trajan

DATING VIA COIN FINDS

- according to the minting date of the coin

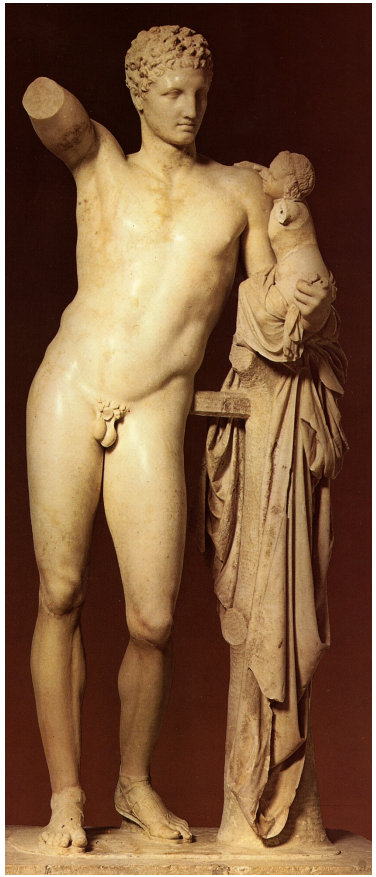
- within the term of the coin

P M TR P COS III P P

Göttingen AS-01299
https://www.kenom.de/objekt/record_DE-MUS-062622_kenom_127696/2/

RELATIVE CHRONOLOGY

e.g. stylistic development of Greek sculpture



Critios Boy (c. 480 BC),

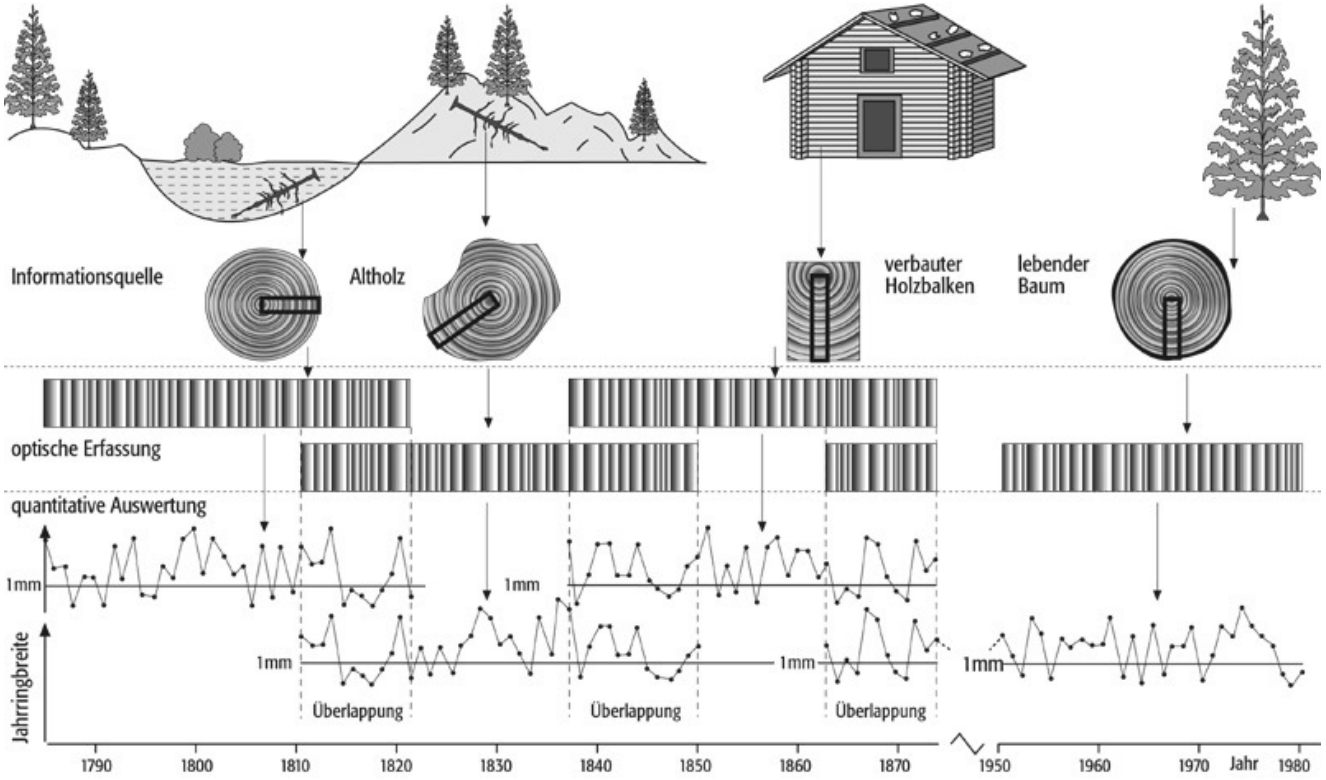
Doryphoros of Polycletus (c. 440 BC),

Hermes of Praxiteles (around 340 B.C.)

DENDRO-CHRONOLOGY

According to the felling date of the tree.

In the case of incomplete sequences, not to be dated exactly to the year.



R.E. Taylor and Martin J. Aitken (eds.), *Chronometric Dating in Archaeology* (Springer, 1997)

DENDRO-CHRONOLOGY

according to the felling date of the tree.

In the case of incomplete sequences, not to be dated exactly to the year.

e.g. oldest oak piles of the Roman bridge of Trier:

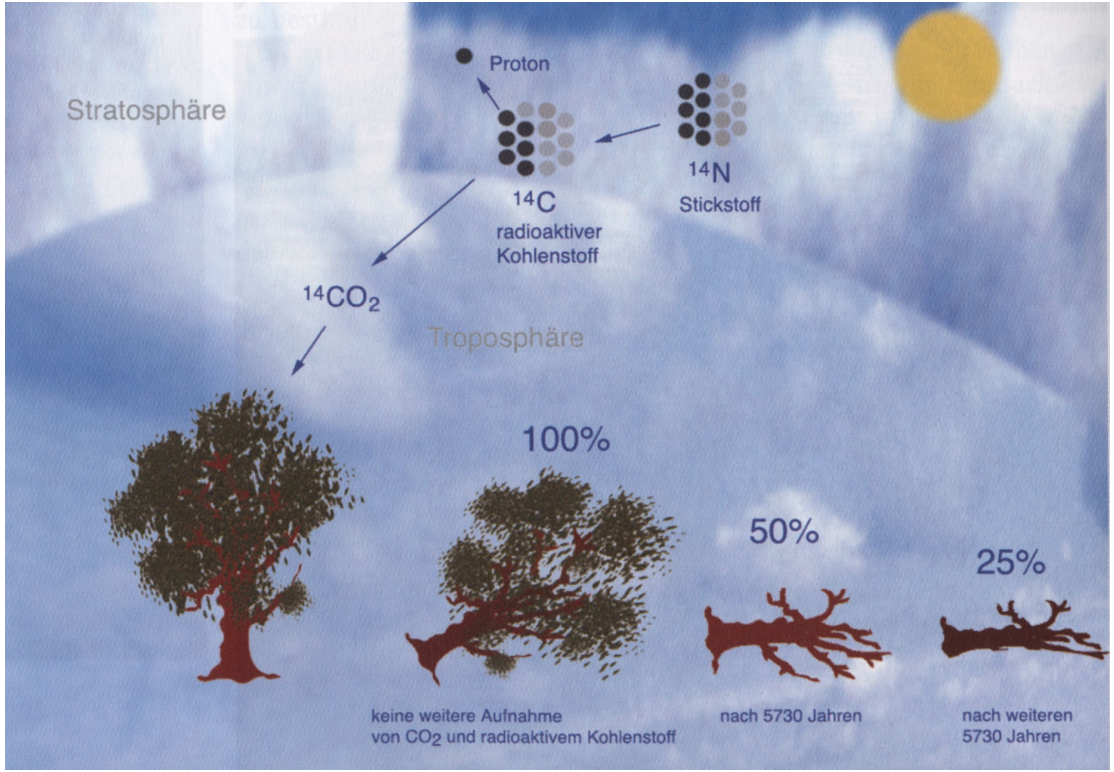
18/17 BC 71 AD

144 AD 315 AD

RADIOCARBON METHOD (C14)

measures the decay of radioactive carbon in organic substances,

relatively imprecise for historical periods, but important for prehistoric archaeology

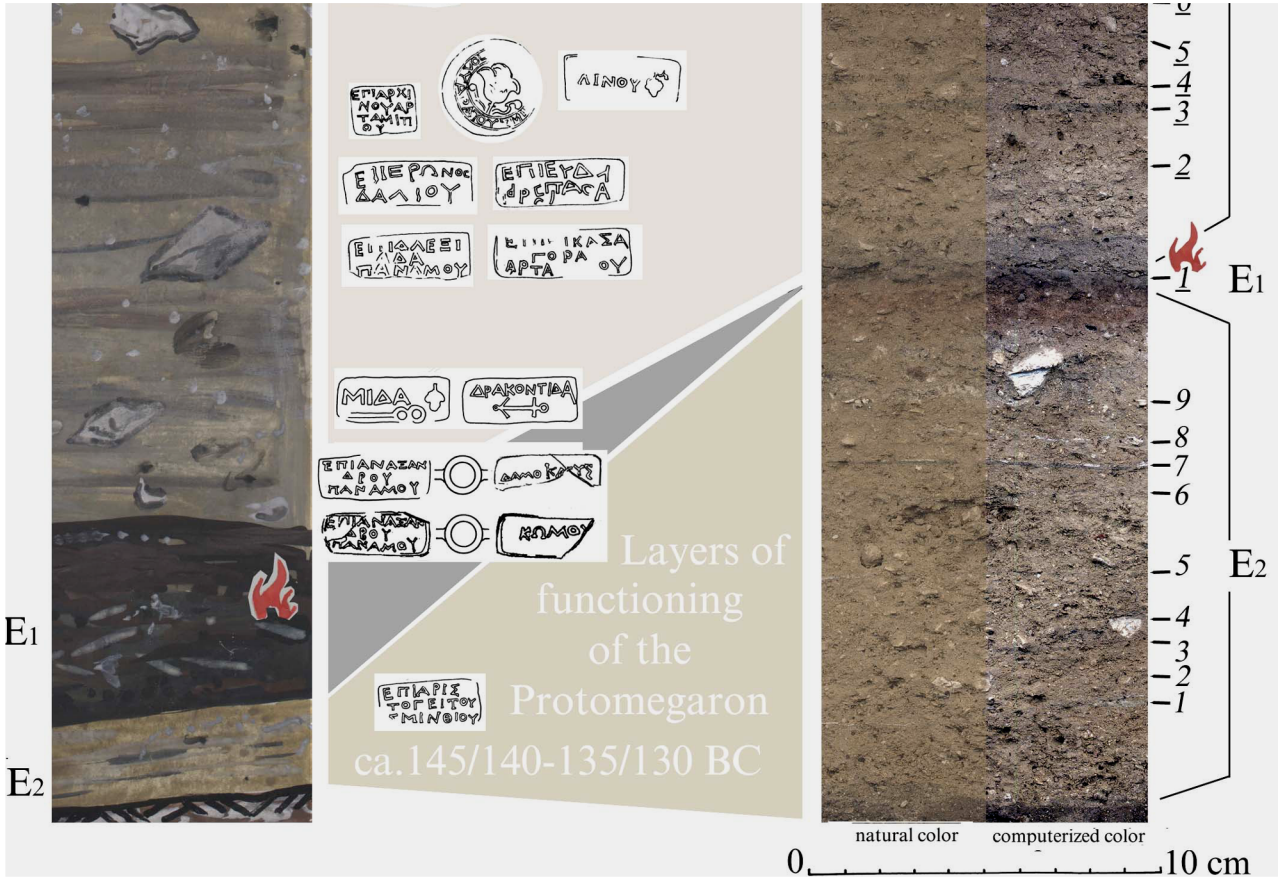


Conversion of calibrated 14C ages into calendar years continuously from today back to 50,000 years ago.

CalPal is freely available as a download or online version (http://monrepos-rgzm.de/forschung/ausstattung.html#calpal)
s.a. Oxford Radiocarbon Accelerator Unit (http://c14.arch.ox.ac.uk/embed.php?File=oxcal.html)

STRATIGRAPHY

Dating of cultural layers via historical events (fire, earthquakes etc.) and finds

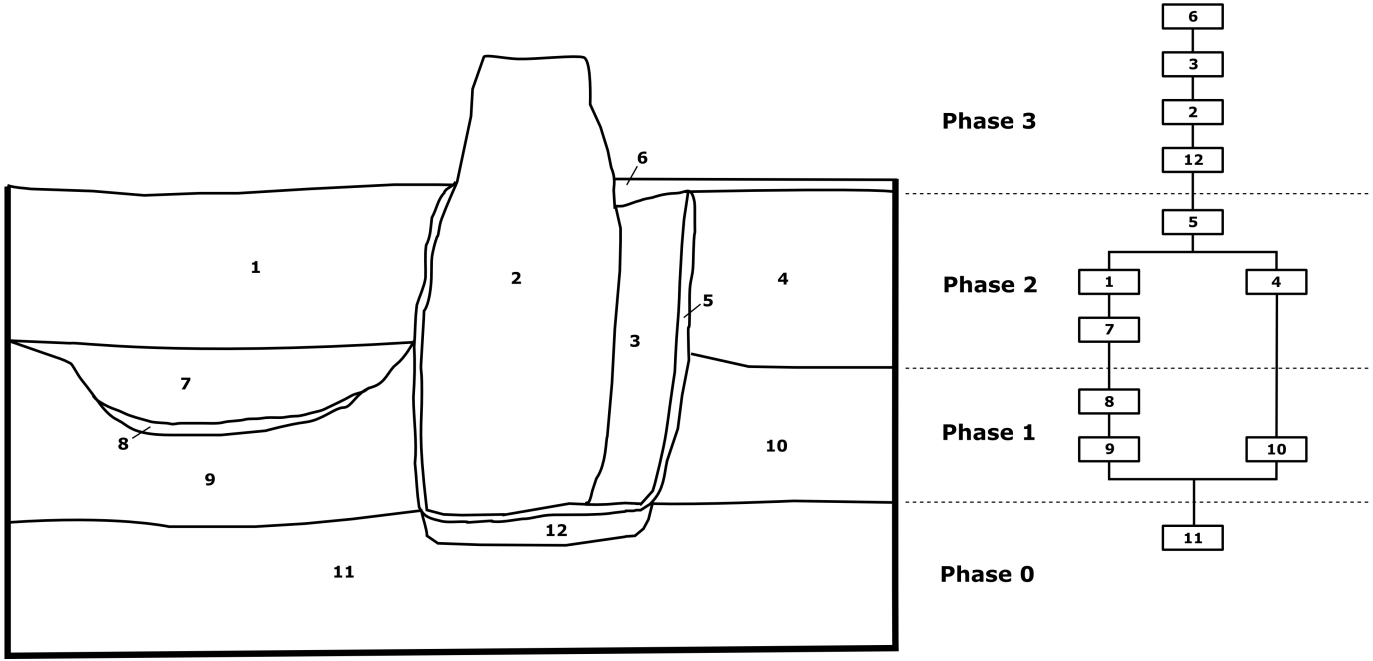


Neapolis Synthicae (Crimea, Ukraine), Stratigraphy

https://antikmuseet.au.dk/fileadmin/www.antikmuseet.au.dk/Pontosfiler/BSS_3/BSS3_13_zaycev.pdf

STRATIGRAPHY: HARRIS-MATRIX

Dating of cultural layers via their relationship to each other



Edward C. Harris, Principles of Archaeological Stratigraphy[2] (London / San Diego 1989)

STRATIGRAPHY: UNCERTAINTY

An Archaeological Information System (AIS) must be able to react appropriately to changes in the interpretation of the features!

Result 1

Stratigraphically, A is later than B.
However, if the finds in B are clearly later than A and there are uncertainties about the stratigraphic relationships, we may decide after the excavation to reinterpret the profile/section as follows:

Result 2

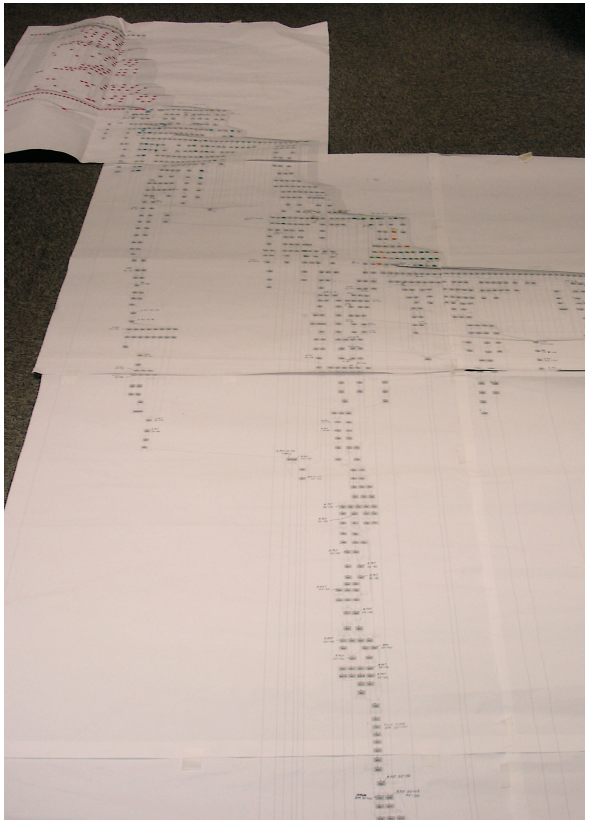
B is later than A.
Alternatively, we could decide that we were mistaken about the finds in B and interpret them as earlier than those in A or as secondary in B.

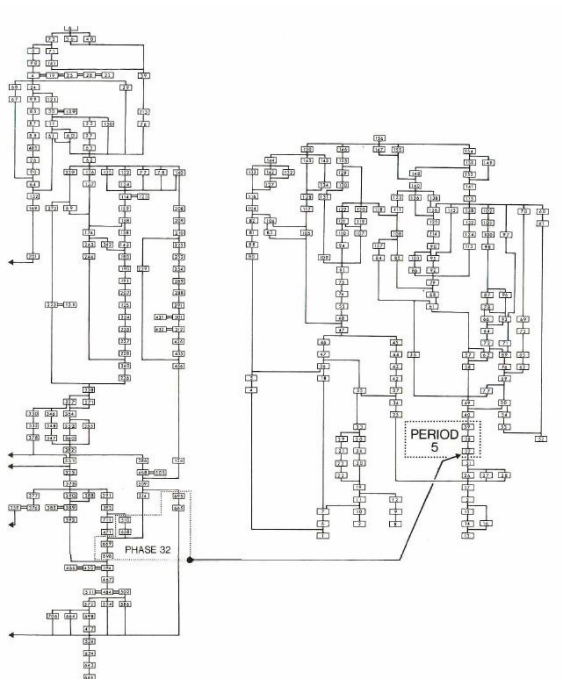
Result 3

Ian Hodder, The archaeological process. An introduction. Oxford: Blackwell 1999, 87 Abb. 5.4

STRATIGRAPHY: HARRIS-MATRIX

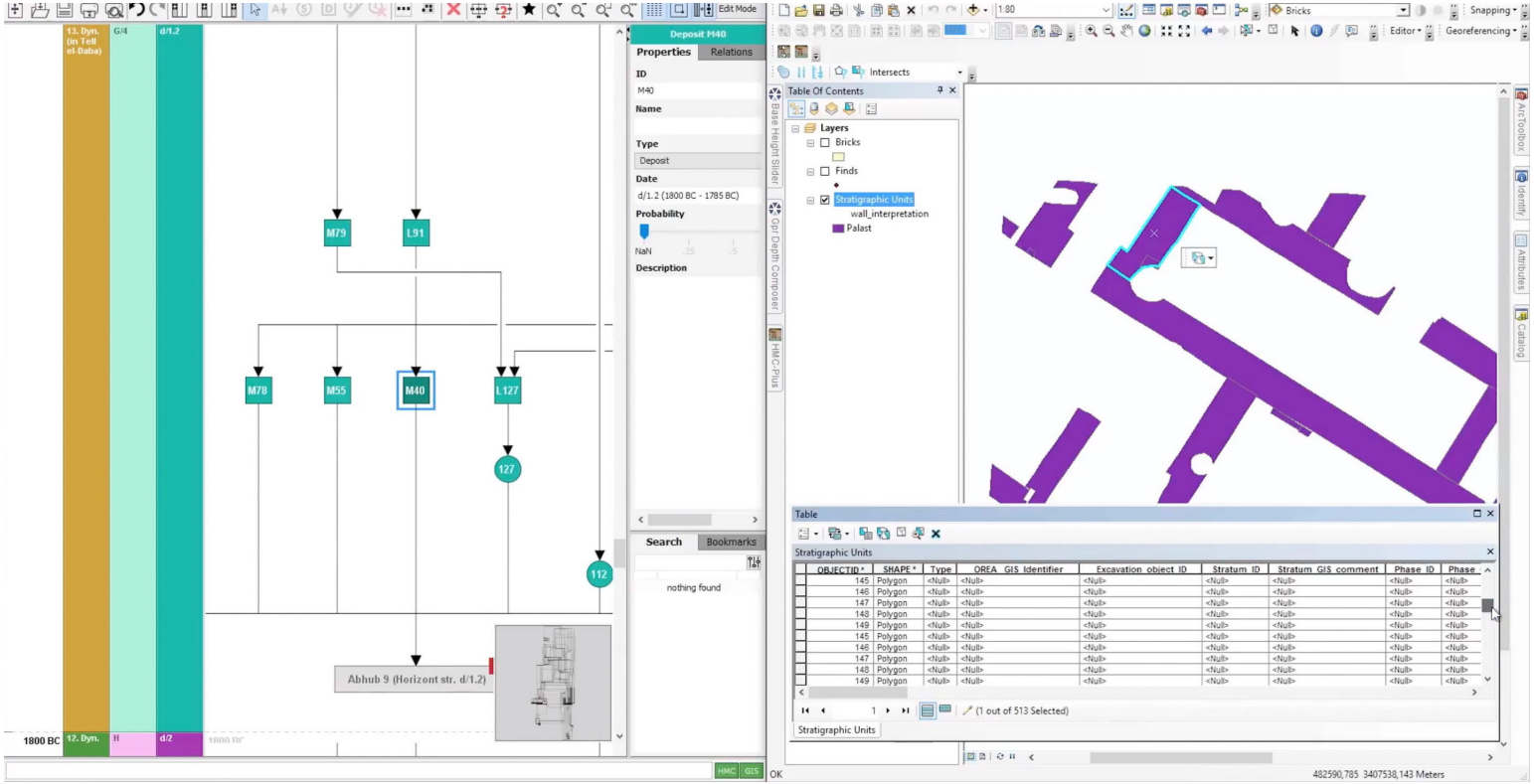
Dating of cultural layers via their relationship to each other





http://www.harrismatrix.com/
http://www.harrismatrixcomposer.com/
https://www.ads.tuwien.ac.at/ArchEd/

TELL EL-DABA ARCHAEOLOGICAL INFORMATION SYSTEM



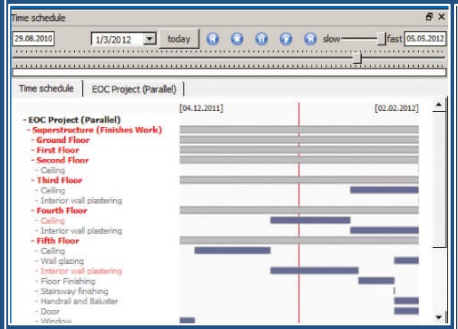
https://youtu.be/rEqhDihwe9U

DATE FORMATS

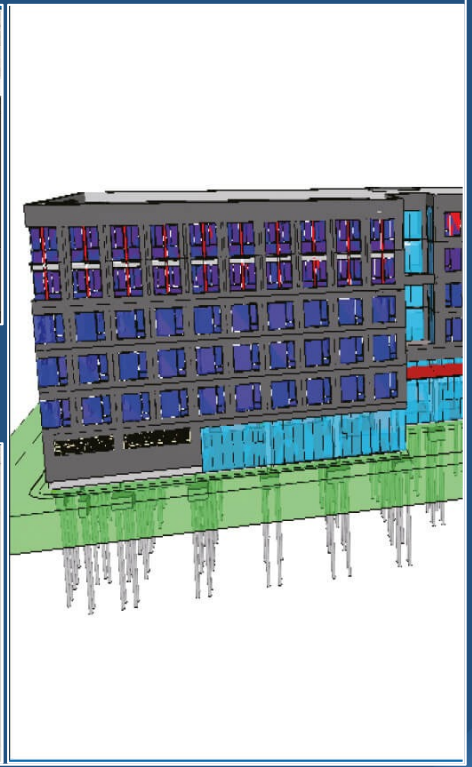
Dating	Example	Data type
BC, AD, BC/AD		Sign (+ / -)
exactly to the day	e.g. 12.05.113 (dedication of Trajan's Column)	DATE
exactly to the year	e.g. 112	INTEGER
to an exact period of time	e.g. 367/66 BC (= {-367; -366} oder {-18.07.367…-07.07.366})	SET, ARRAY
to an approximate period of time	e.g. ca. 20–10 BC, mittle Augustan, later 1st cent. BC	(SET, ARRAY)
before or after a period	before 79, the eruption of Vesuvius	(SET, ARRAY)
before or after a period	stratigraphic result	(SET, ARRAY)

THE DIGITAL MODELLING OF SPACE AND TIME

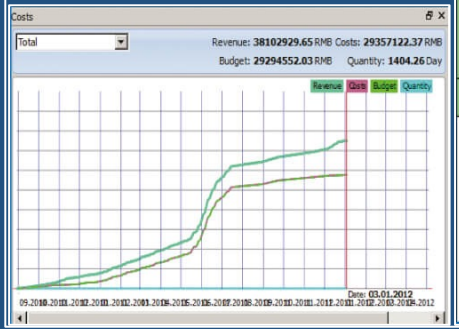
4D Time

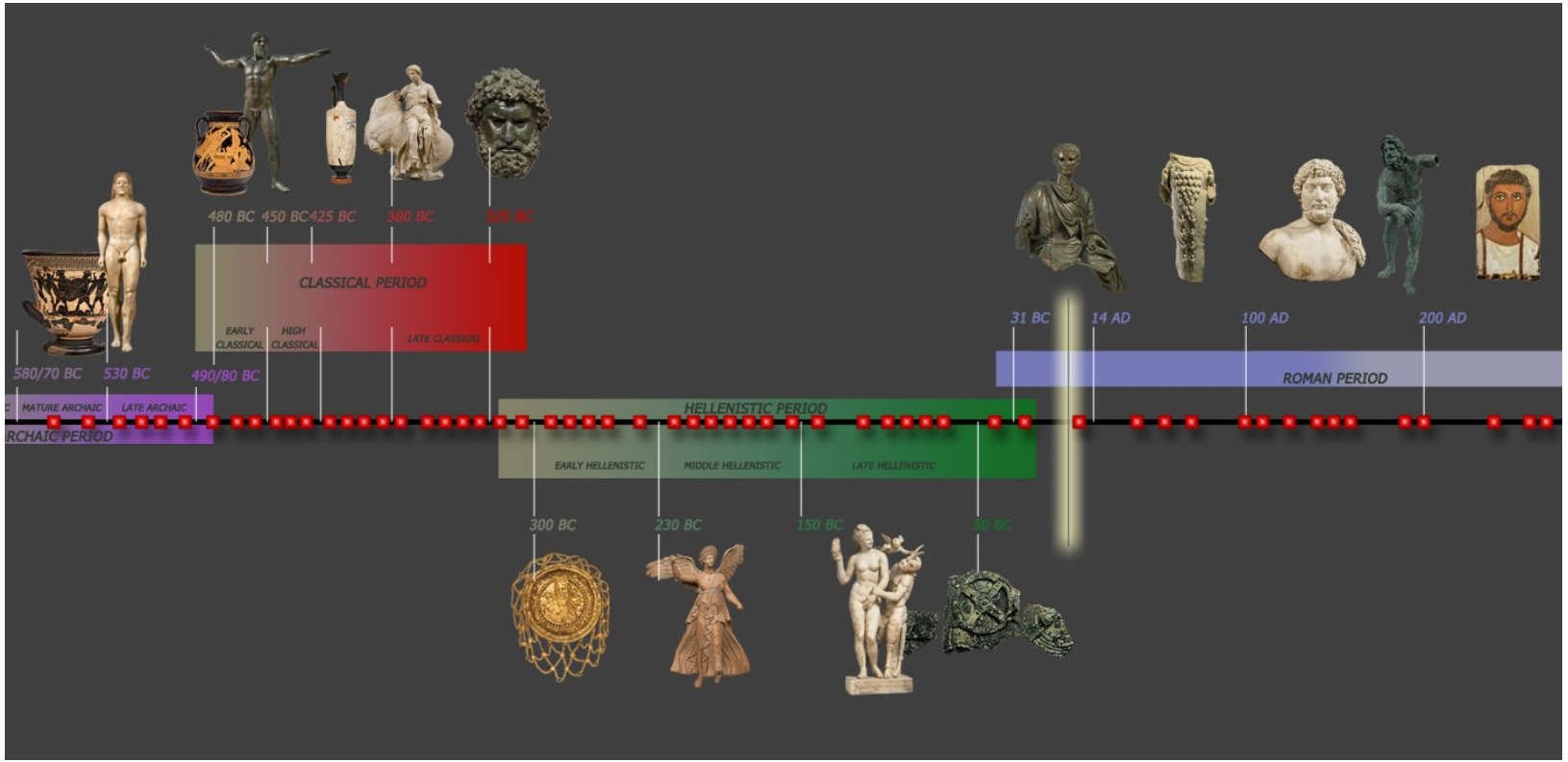


3D Space



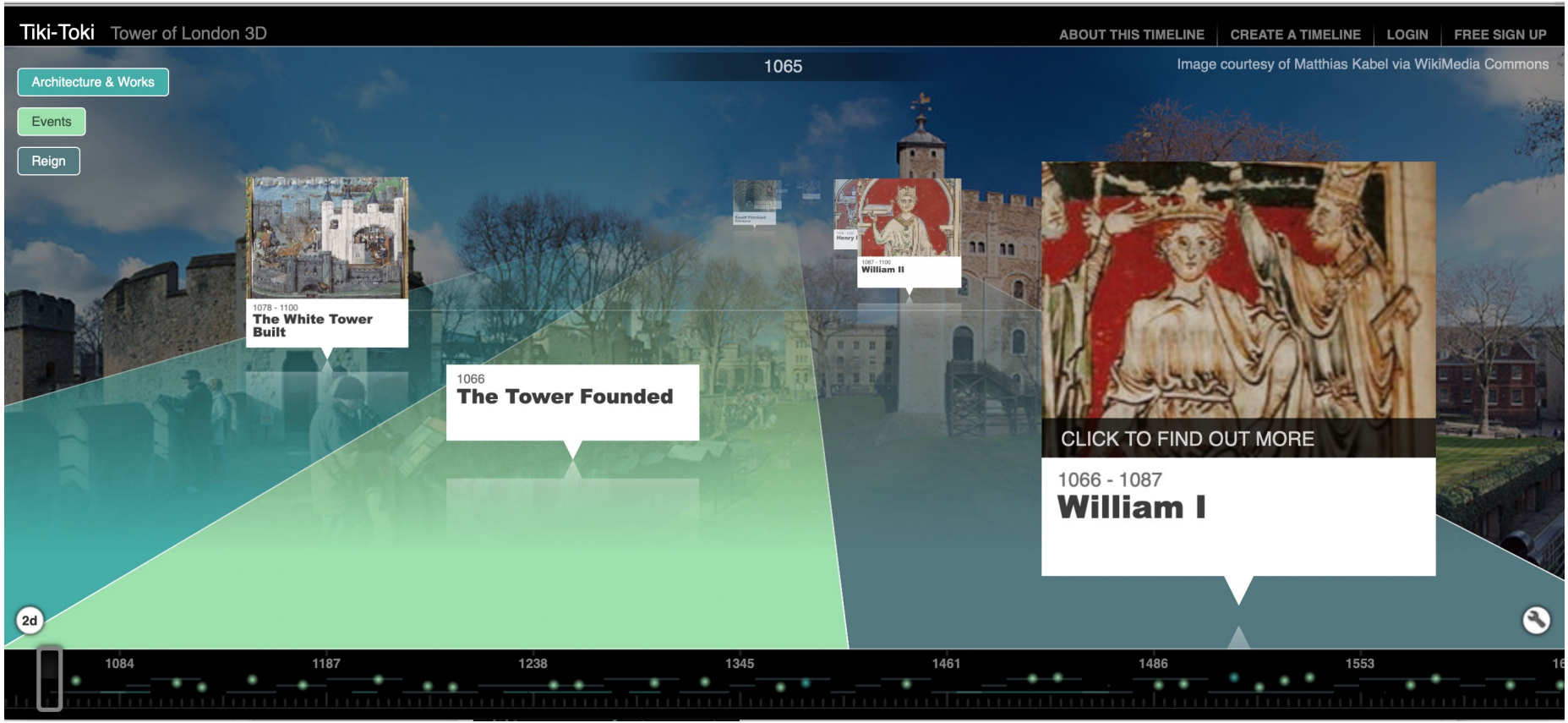
5D Costs



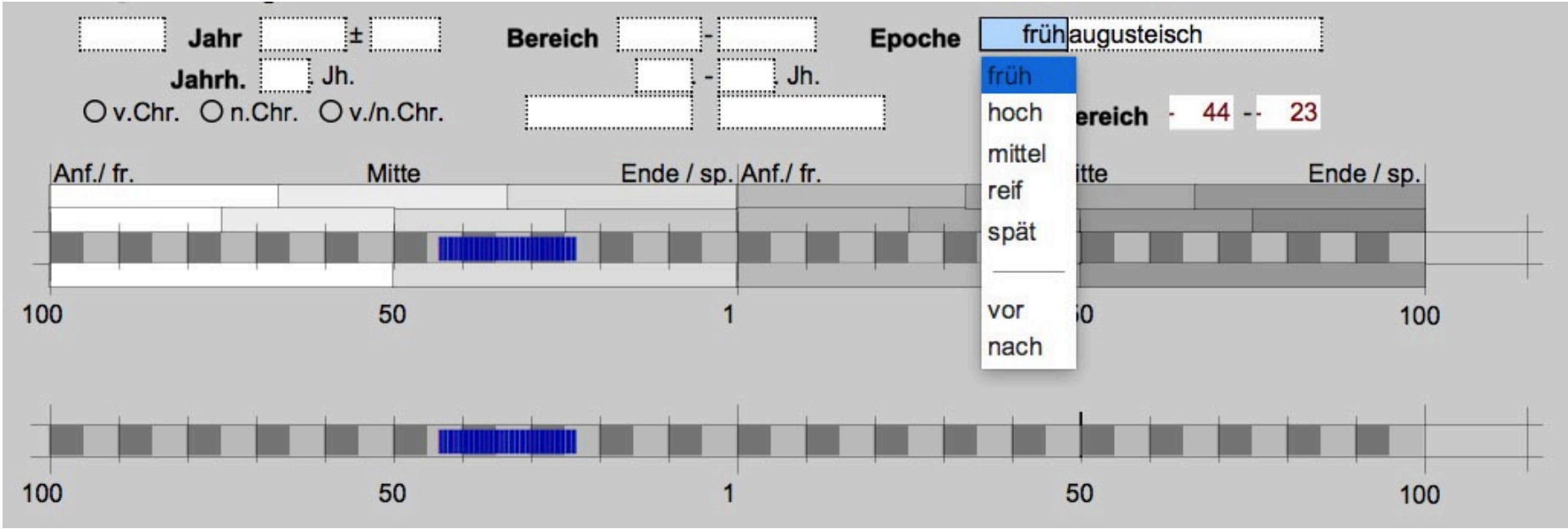


www.namuseum.gr

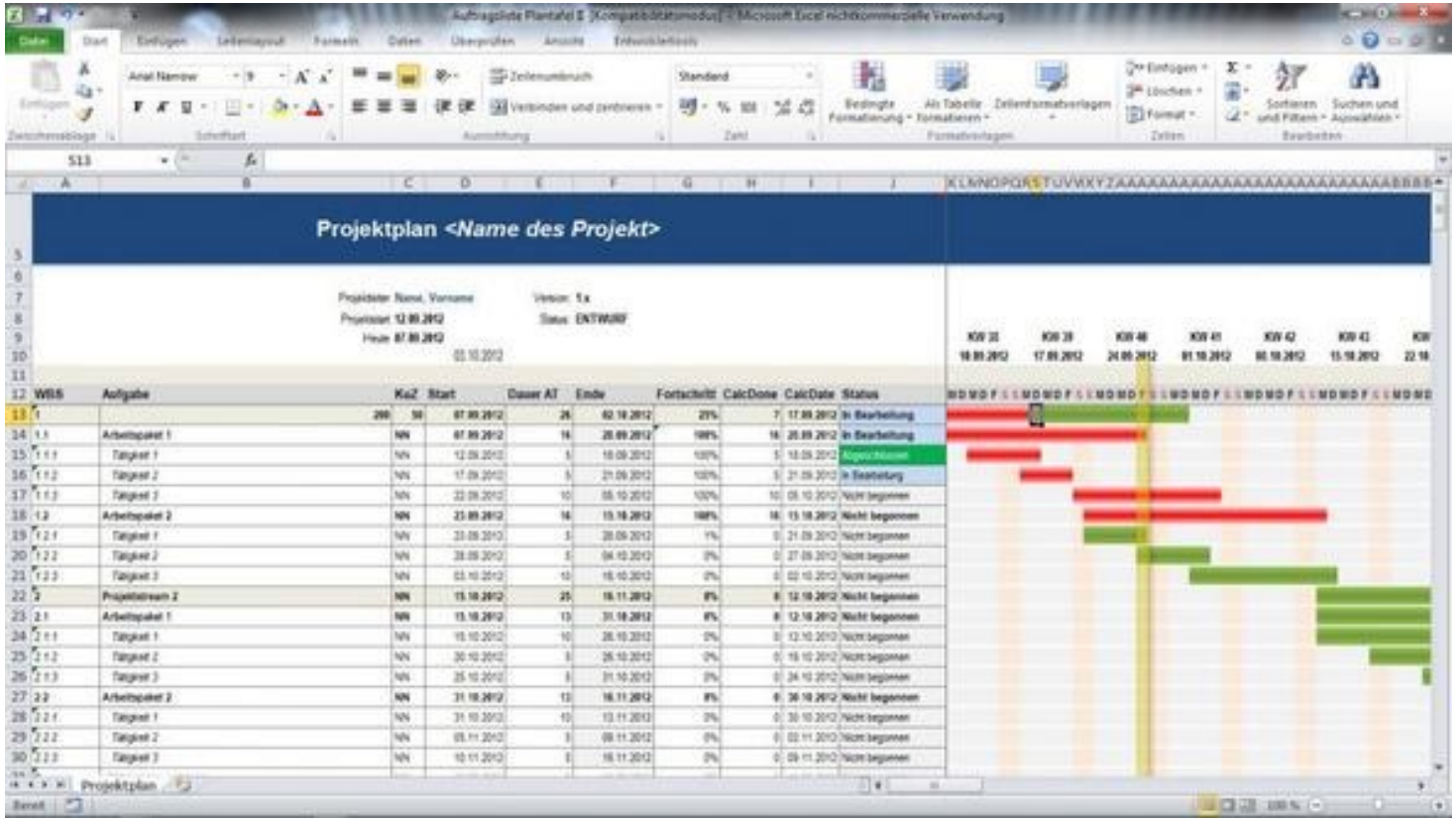
Daniel Rosenberg and Anthony Grafton, *Cartographies of Time: A History of the Timeline* (New York: Princeton Architectural Press 2009)



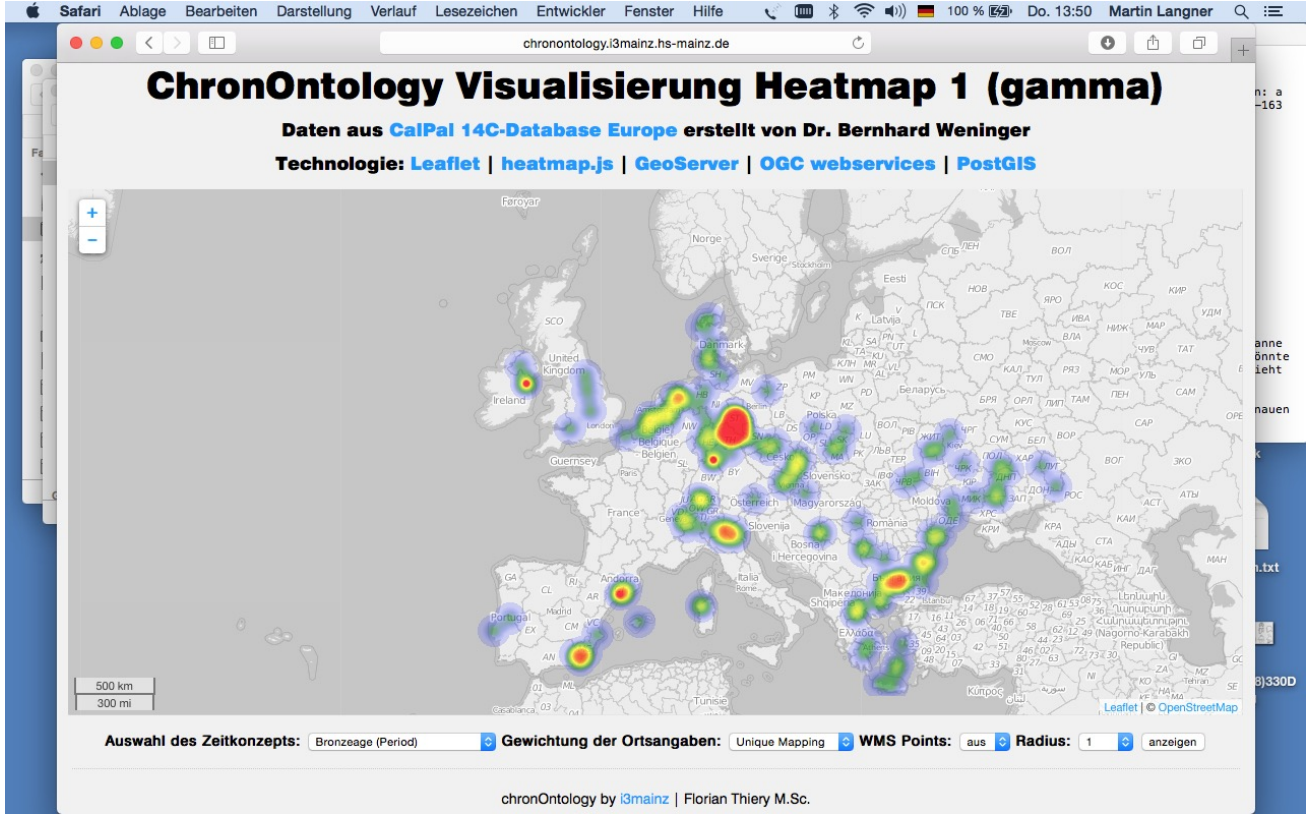
www.tiki-toki.com



- linguistic datelines that contain values as text
- numerical timelines containing numerical values
- interactive, clickable, zoomable

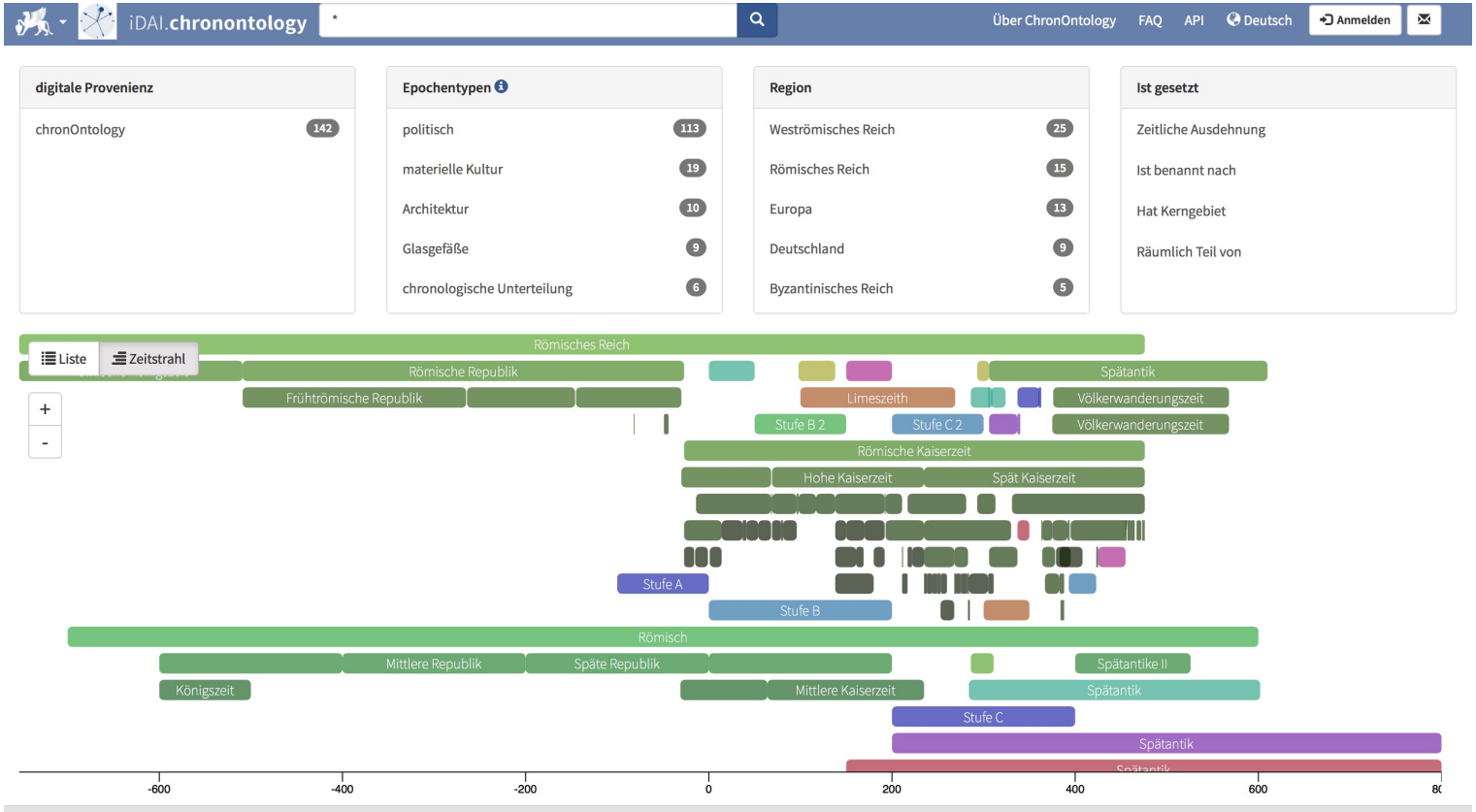


Example: Project planning with Excel



https://chronontology.dainst.org

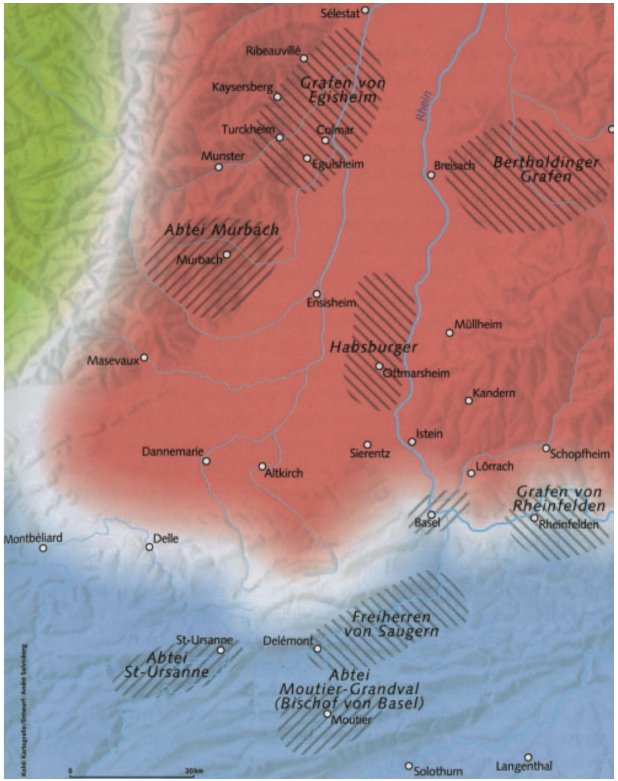
ONTOLOGY FOR CORRELATION OF TIME PERIODS



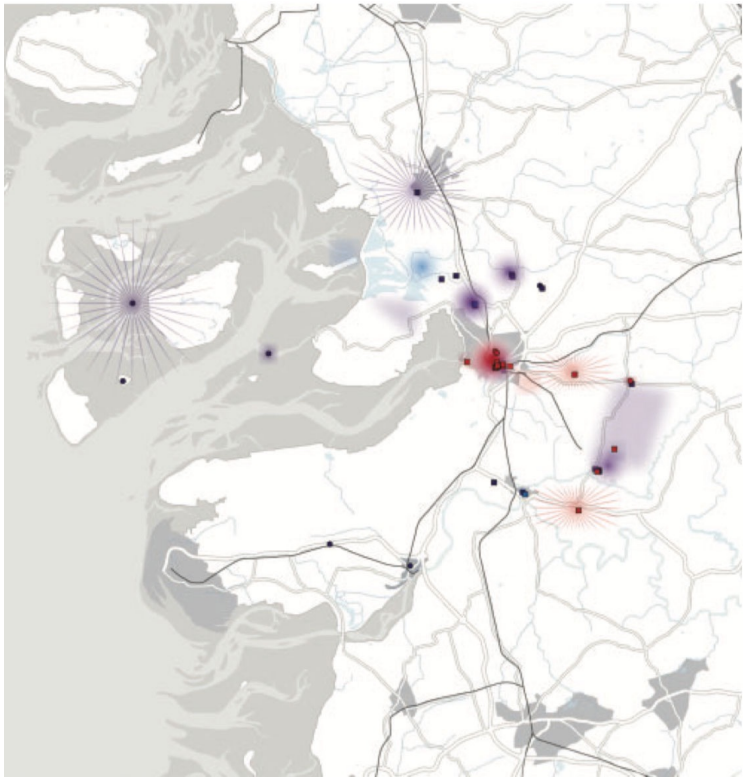
https://chronontology.dainst.org

Category	Examples for Space	Examples for Dating
Uncertainty	Hand sketch, undocumented boundaries	"ca. 300", "+/- 10 min."
Lack of precision	"near Rome", abbreviated coordinates	"once a week", „later Imperial Period“
Lack of unambiguity	"Newport“, spelling variance	"ca. 300" ↔ "ca. 305"
Incompleteness	due to light conditions, overgrowth	Gaps in tradition,
Inconsistency	"from Rome"/ "in Rome"	"12h" (12 hours/12 o‘clock)
Limited validity	Age of the maps	Different chronology systems
Credibility	Local Knowledge?	Pre- or backdating
Subjectivity	Local ↔ Foreign	Experts ↔ Students
Interrelation	Modified version of a map	Anachronism
Error in acquisition	Multiple input sources	Conversion problems

A. MacEachren et al., "Visualizing Geospatial Information Uncertainty: What We Know and What We Need to Know," in *Cartography and Geographic Information Science* 32.3 (2005), 139–160: www.researchgate.net/publication/216756513

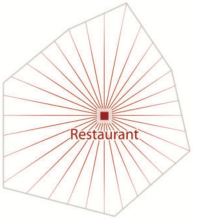


Principalities around 1000 AD, Historischer Atlas der Region Basel. Geschichte der Grenzen (Salvisberg, 2010)

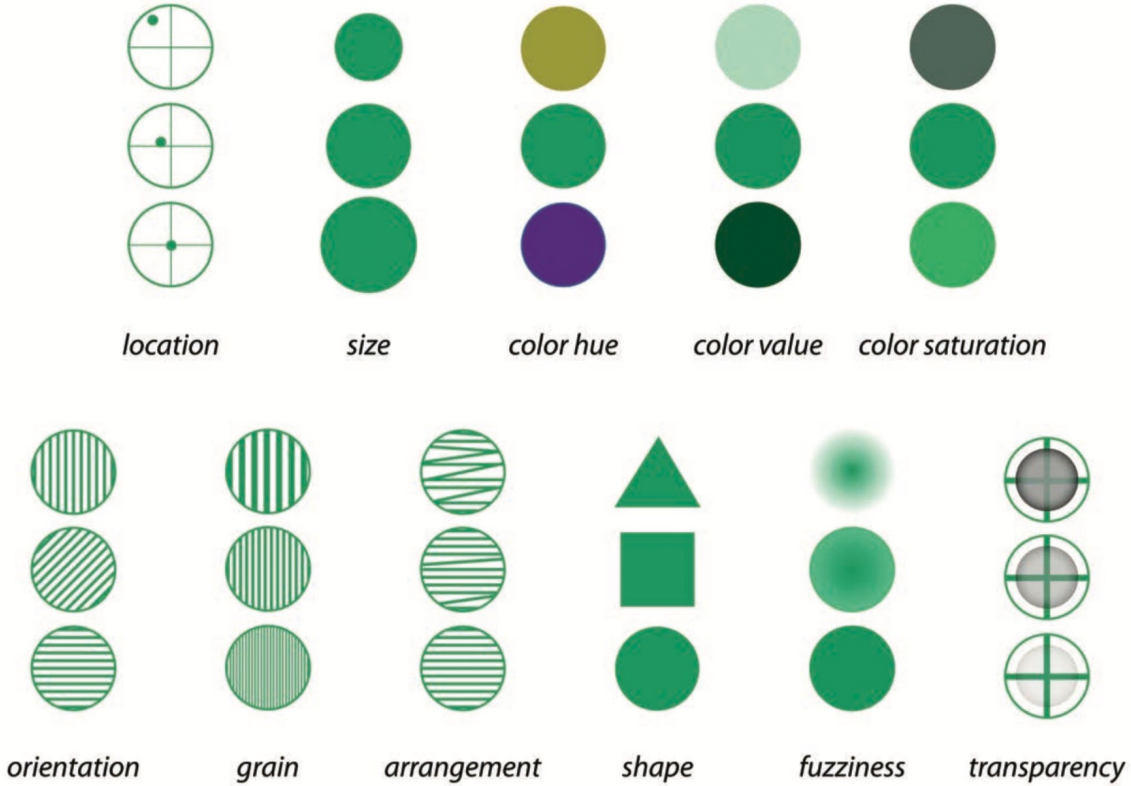


Locations in Theodor Storm's novella "The Rider on the White Horse"

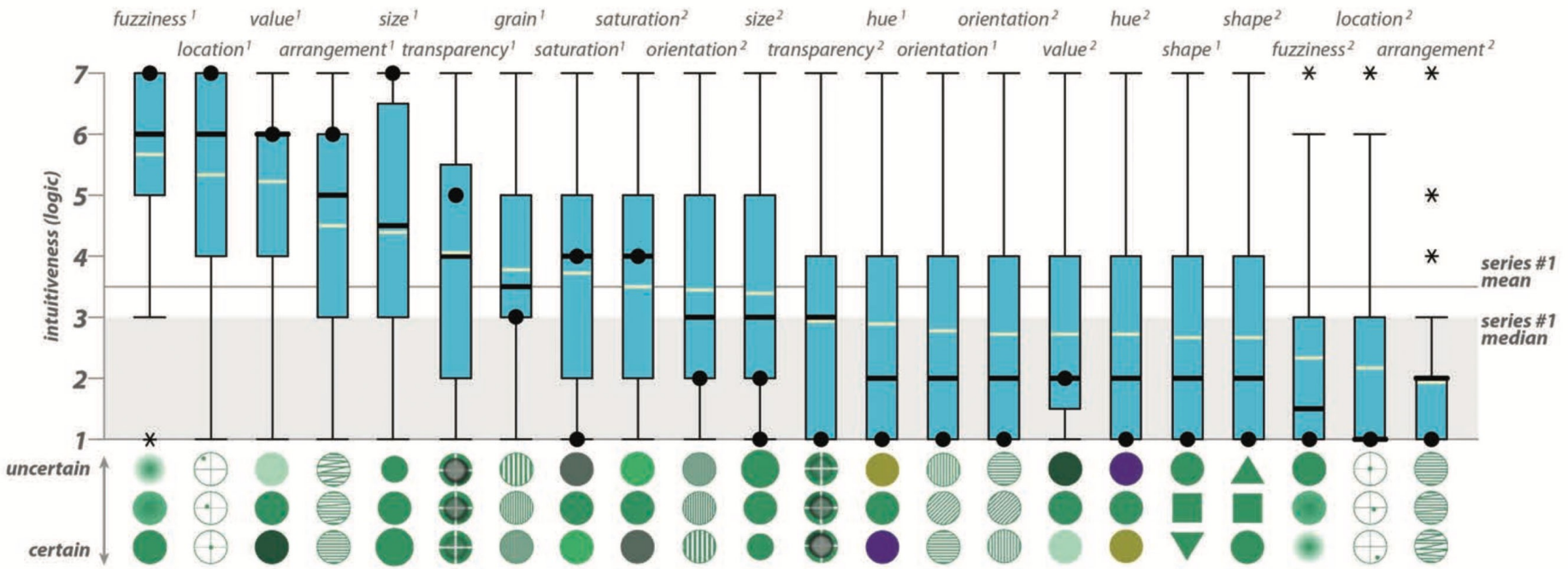
Anne-Kathrin Reuschel and Lorenz Hurni, Mapping Literature: Visualisation of Spatial Uncertainty in Fiction, The Cartographic Journal 48 no. 4 (2011), 293–308: http://www.literaturatlas.eu/files/2012/02/Reuschel2011_CAJ.pdf



THE VISUAL VARIABLES

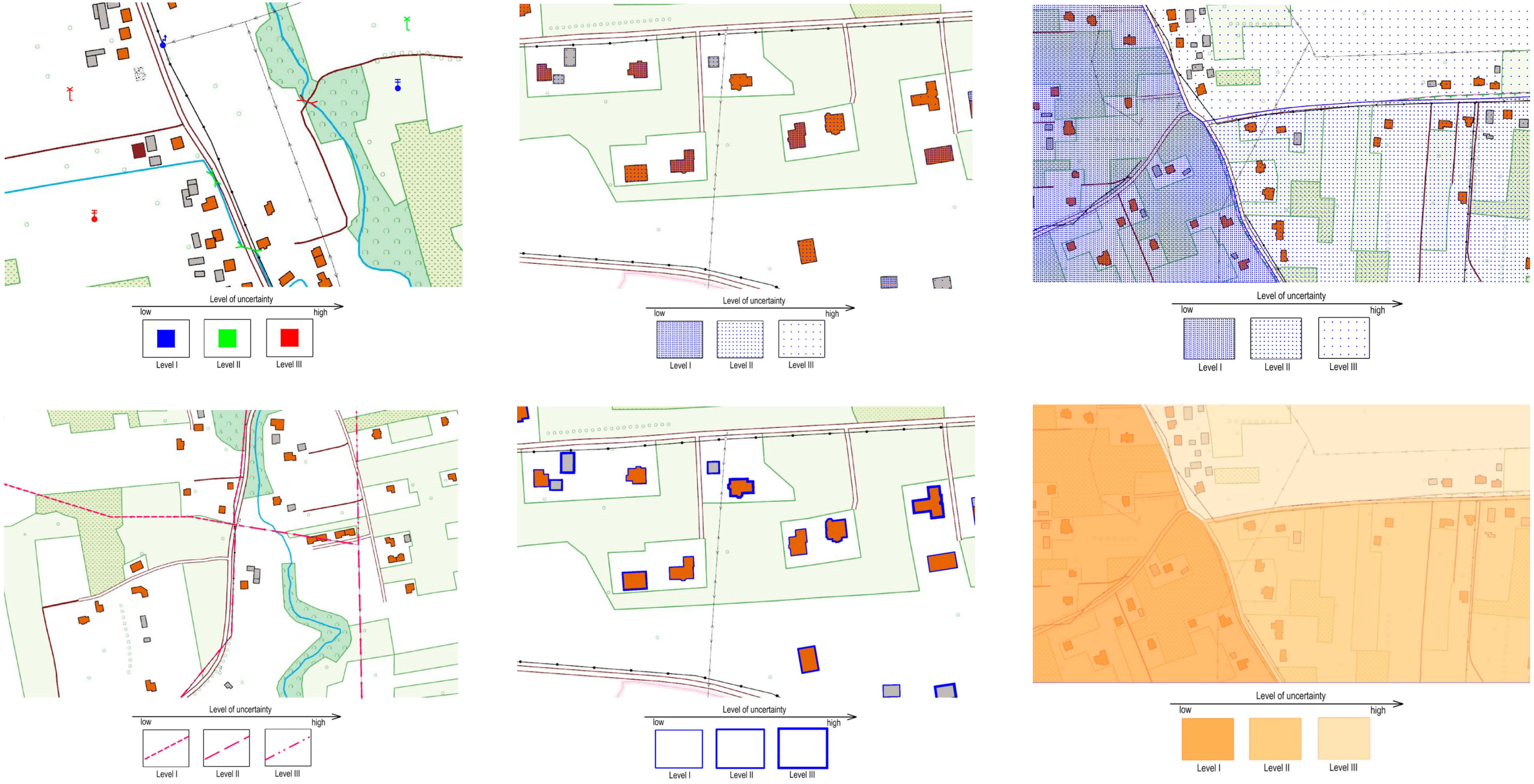


A. MacEachren et al., "Visual Semiotics & Uncertainty Visualization: An Empirical Study," *IEEE Transactions on Visualization and Computer Graphics* 18, no. 12 (2012), 2496–2505: www.researchgate.net/publication/260582970

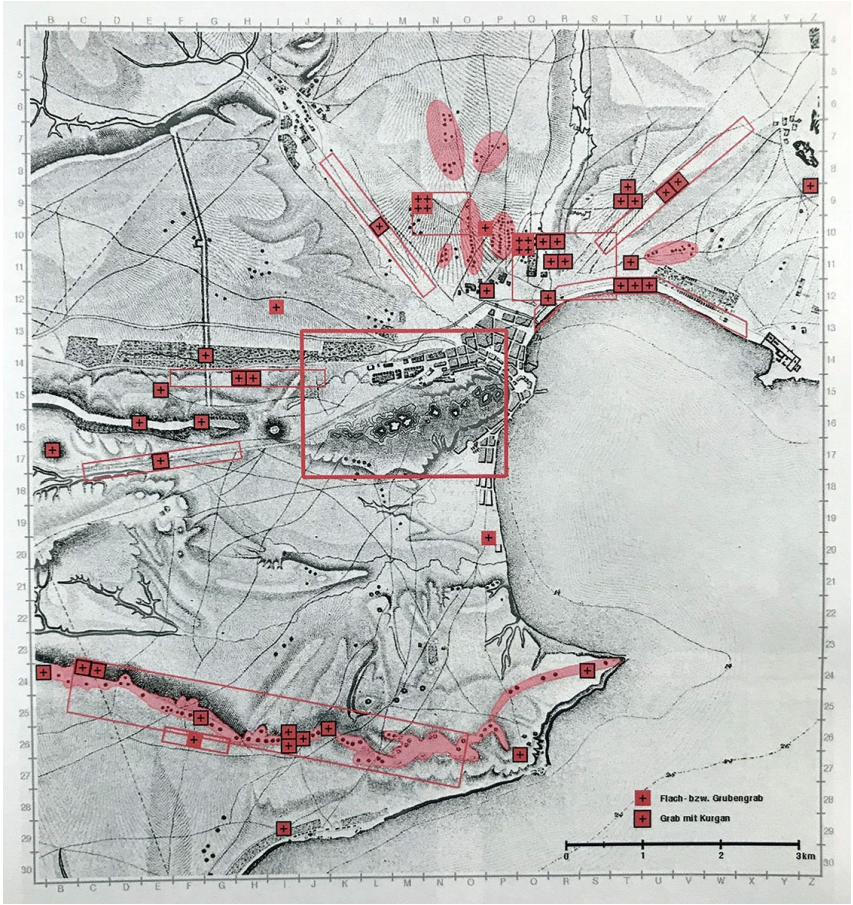


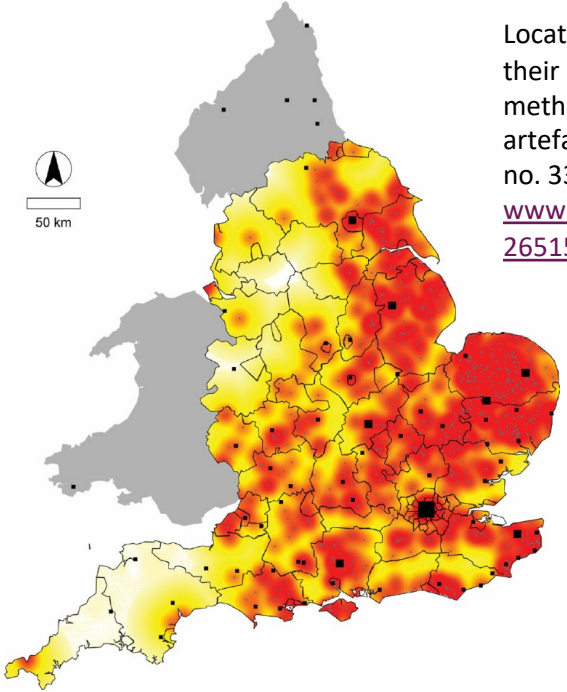
A. MacEachren et al., "Visual Semiotics & Uncertainty Visualization: An Empirical Study," *IEEE Transactions on Visualization and Computer Graphics* 18, no. 12 (2012), 2496–2505: www.researchgate.net/publication/260582970

VISUALISATION OF SPATIAL UNCERTAINTY



Marek Ślusarski and Magdalena Jurkiewicz, Visualisation of Spatial Data Uncertainty. A Case Study of a Database of Topographic Objects, ISPRS International Journal of Geo-Information 9 no. 1 (2020), 16; https://doi.org/10.3390/ijgi9010016





Locations of Anglo-Saxon coins and their range. Andrew Bevan, Spatial methods for analysing large-scale artefact inventories, Antiquity 86 no. 332 (2012), 492–506: www.researchgate.net/publication/265151629

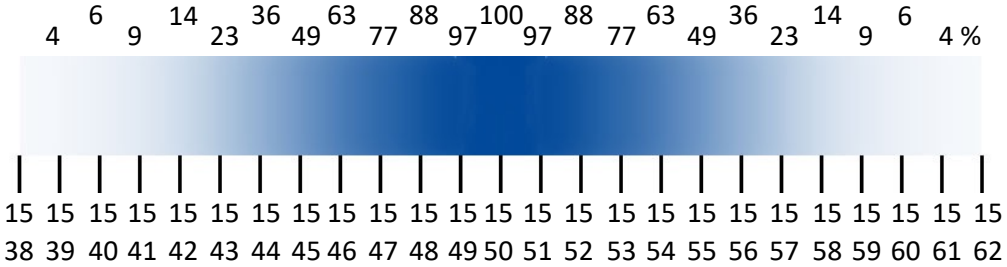
F. Fless – A. Lorenz, Die Nekropolen Pantikapaions im 4. Jh. v. Chr. in: F. Fless – M. Treister (Hrsg.), Bilder und Objekte als Träger kultureller Identität und interkultureller Kommunikation im Schwarzmeergebiet, Kolloquium in Zschortau/ Sachsen vom 13.-15. Februar 2003, ASTK 6 (2005) 17-26 Taf. 3

https://upload.wikimedia.org/wikipedia/commons/thumb/d/d2/Carlos_V_en_Mühlberg%2C_by_Tiziano_%2C_from_Prado_in_Google_Earth.jpg

CHRONOLOGICAL UNCERTAINTY

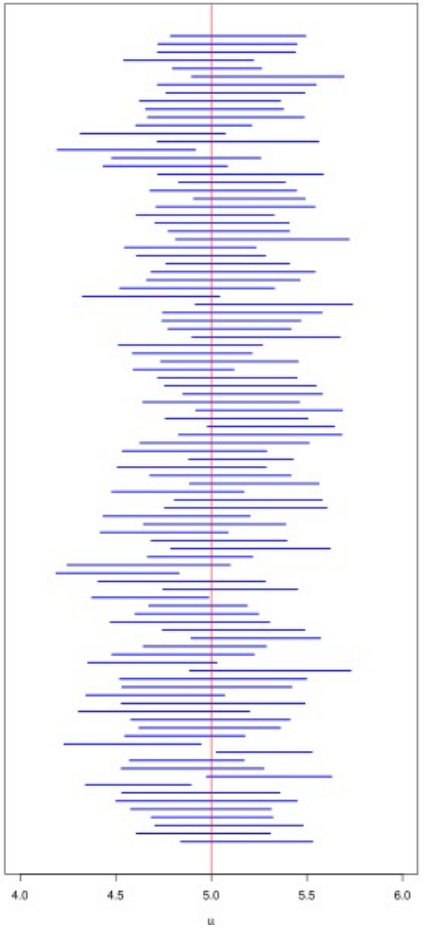
e.g. „Middle of the 16th century“ ≈ „1545–1555“

Middle of the 16th century: Titian paints the painting "Emperor Charles V after the Battle of Mühlberg"
24th April 1547: Charles V defeats the troops of the Schmalkaldic League in the Battle of Mühlberg



CHRONOLOGICAL UNCERTAINTY

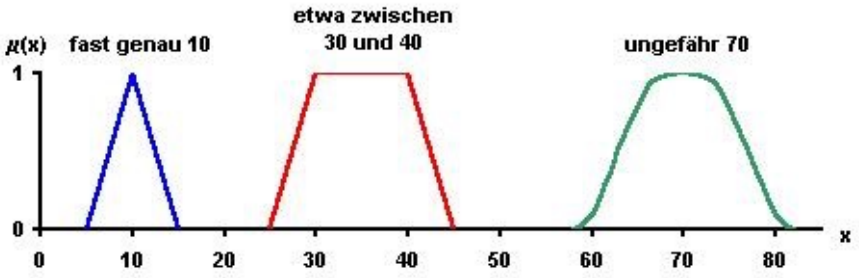
could also be modelled as a confidence interval, i.e. as a range in which the dating information is located with a certain probability.
However, this approach presupposes measurable values, which are usually not available for dating.



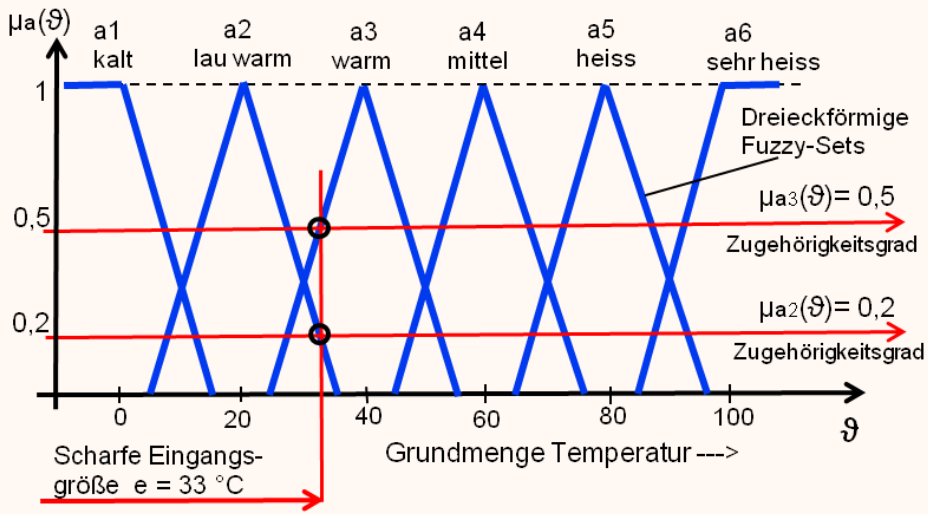
Confidence intervals at the 95 % level for 100 samples of size 30 from a normally distributed population. Of these, 94 intervals cover the exact expected value μ = 5; the remaining 6 do not.
(http://de.wikipedia.org/wiki/Konfidenzintervall)

CHRONOLOGICAL UNCERTAINTY

Fuzzy set theory operates with indeterminate conceptual scopes in the sense of referential semantics. This procedure, which is based on the theory of fuzzy sets, could also be applied to humanities data sets and search results by actually visualising the data as fuzzy sets whose density decreases at the edges, whereby linking and overlapping is also possible.



FUZZY SET THEORY



Subjektive linguistische Begriffe der Temperatur

* Darstellung Fuzzy-Variable A der Temperatur mit ihren Termen a1.....a6.
* Überlappungen der Fuzzy-Sets zwischen 20% bis 50 % sind üblich.
* Symmetrie der dreieckförmigen Fuzzy-Sets ist nicht zwingend.
* 2 Fuzzy-Sets a2 und a3 sind wie dargestellt aktiv ("feuern").
* Fuzzifizierung e1 = 33°C → $\mu_a(\vartheta) = \{0;\ 0{,}2;\ 0{,}5;\ 0;\ 0;\ 0\}$

Representation of a fuzzy basic set A with 6 subsets a1 ... a6 (http://de.wikipedia.org/wiki/Fuzzy-Regler)

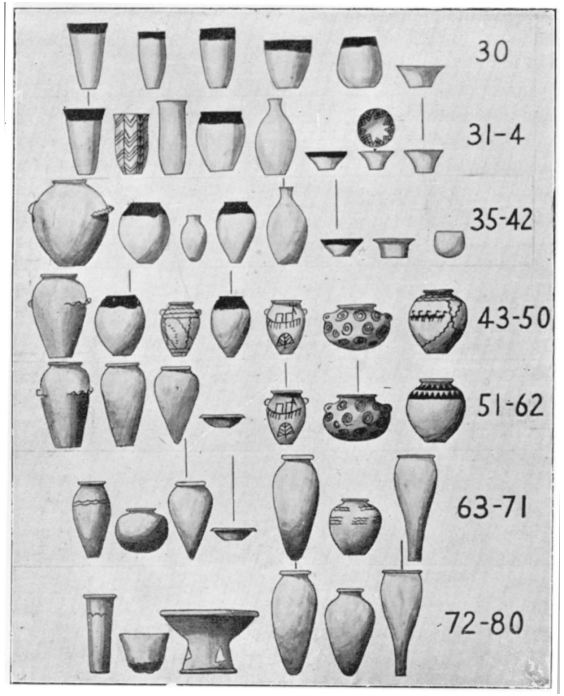
CONTEXTUAL SERIATION

of the named vessel types and graves 1-7:
1 = Context contains the vessel type
0 = Context does not contain the vessel type

	ABCDEFG	
beaker	0000110	beaker
blackrim	1000110	blackrim
bottle	1000100	bottle
handle	0101000	handle
spirals	1001001	spirals
flatpot	0111000	flatpot
pointed	0001001	pointed
	ABCDEFG	

	ABCDEFG	
beaker	..**	beaker
blackrim	*..**	blackrim
bottle	*..*.	bottle
handle	.*.*.	handle
spirals	*.*.*	spirals
flatpot	.***.	flatpot
pointed	...*.*	pointed
	ABCDEFG	

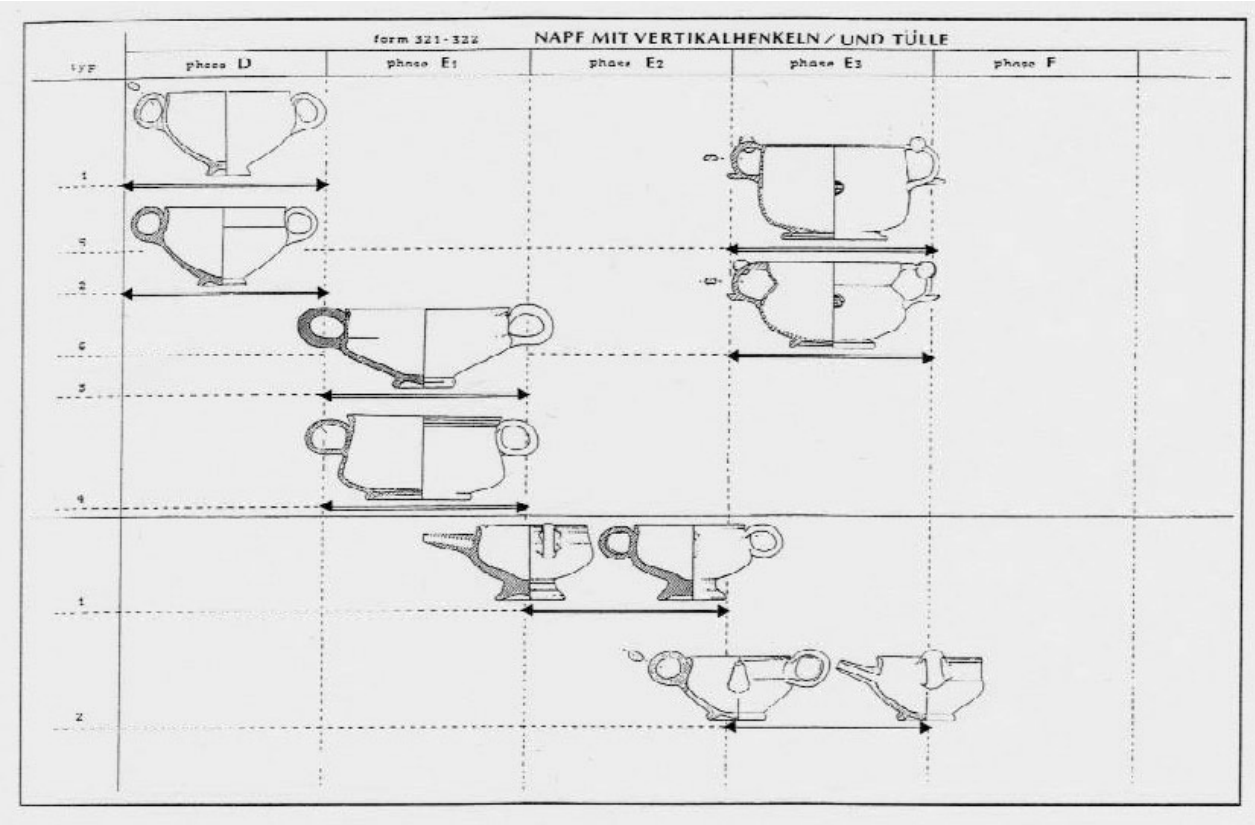
	FEAGDBC	
beaker	**	beaker
blackrim	***	blackrim
bottle	.**	bottle
flatpot	..***	flatpot
handle	...**	handle
pointed	...**	pointed
spirals	...***	spirals
	FEAGDBC	



Flinders W. M. Petrie, Sequences in prehistoric remains. Journal of the Anthropological Institute 29, 1899, 295–301; C. Renfrew – P. Bahn, Archaeology. Theories, Methods, and Practice (London 1996) 117; Johannes Müller – Andreas Zimmermann (Hrsg.), Archäologie und Korrespondenzanalyse. Beispiele, Fragen, Perspektiven (Rahden/Westf. 1997); K. Kris Hirst, An Introduction to Seriation (http://archaeology.about.com/od/dating/ss/seriation.htm)

SERIATION

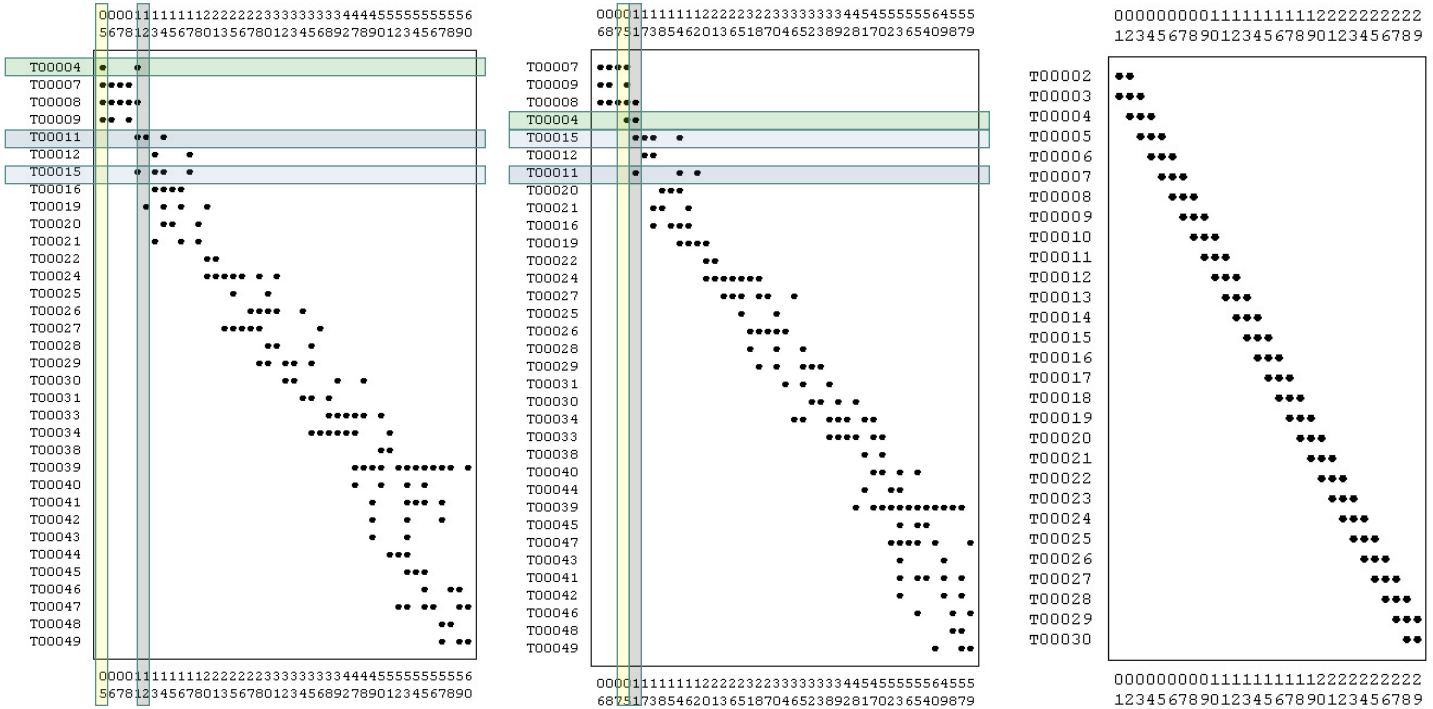
of grave goods using the example of Taranto



Daniel Graepler, Relativchronologische Ordnung hellenistischer Keramik aus der Nekropole von Tarent mit Hilfe der Korrespondenzanalyse, in: Δ' επιστημονικη συναντηση για την ελληνιστικη κεραμικη, Mytilene 1994, Praktika (Athen 1997) 170 Vgl. auch D. Graepler, Tonfiguren im Grab (München 1997) 67 f. und 76 f. zum Typenbegriff.

SERIATION

Rearrangement of rows and columns of the table to a diagonal in the table



Rohdaten (unsortiert) | Daten sortiert | Idealtypische Seriation

CHALLENGES

- Modelling of chronological fuzziness with regard to statistical evaluability
- Visualisation and evaluation of uncertainty in geodata
- Increasing the flexibility of acquisition in archaeological information systems
- Retro-digitisation and evaluation of unstructured data

- Definitions and concepts of cultural heritage
- Possibilities of digital geoarchaeology and excavation documentation
- Basics of historical cartography, surveying and geo-referencing and their digital implementation
- Different dating methods and chronology systems and their digital modelling
- GIS / CAD data and their integration, geo-databases, geo-repositories
- Approaches to modelling and visualising uncertainty in spatial and temporal data

- Dealing with time and geodata
- Visualisation of historical situations and archaeological features on maps and in GIS
- Practical experience in the use of GIS and archaeological databases with regard to different usage scenarios

What dating options are available to the historical sciences?

Slide 6. 62–71

How can dating be expressed linguistically? What difficulties does this pose for digital processing?

Slide 72. 74–80

What are the benefits of digital geovisualisation?

Slide 29

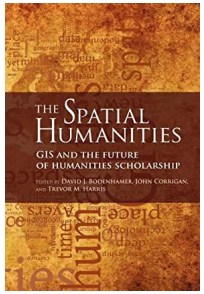
Give two examples of digital processing of spatial data.

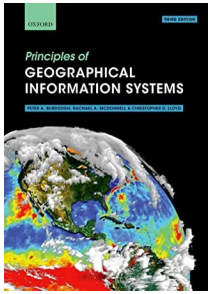
Slide 26–32

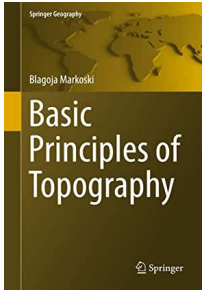
What is meant by the term cultural heritage? What opportunities does digital acquisition offer here?

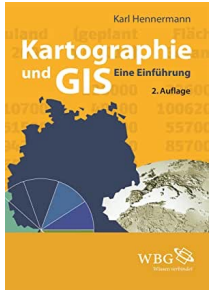
u.a. Slide 2–3

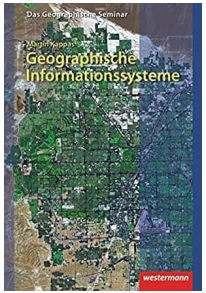
What do you think a historical geo-information system should be able to do?

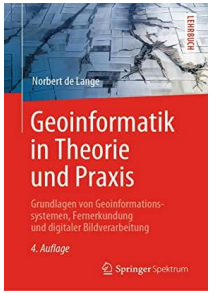












David J. Bodenhamer, Spatial Humanities: GIS and the Future of Humanities Scholarship (Indiana: 2010).

Peter A. Burrough, Rachael A. McDonnell, and Christopher D. Lloyd, Principles of Geographical Information Systems (Oxford 2015).

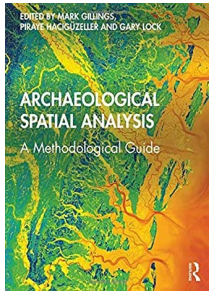
Christoph Siart, Markus Forbriger and Olaf Bubenzer (eds.), Digital Geoarchaeology: New Techniques for Interdisciplinary Human-Environmental Research (Springer, 2018)

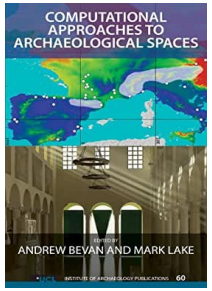
Blagoja Markoski, Basic Principles of Topography (Springer, 2019)

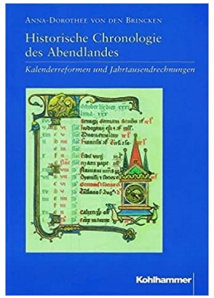
Karl Hennermann, Kartographie und GIS: Eine Einführung (Darmstadt: WBG, 2014).

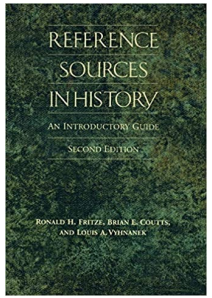
Martin Kappas, Geographische Informationssysteme (Braunschweig: westermann, 2012).

Norbert de Lange, Geoinformatik in Theorie und Praxis: Grundlagen von Geoinformationssystemen, Fernerkundung und digitaler Bildverarbeitung (Springer, 2020).









Mark Gillings, Piraye Hacigüzeller and Geary Lock, Archaeological Spatial Analysis. A Methodological Guide (Routledge, 2020)

Andrew Bevan und Mark Lake, Computational Approaches to Archaeological Spaces (Routledge, 2016)

Stuart Dunn, A History of Place in the Digital Age (Routledge, 2019)

Marieluise Deißmann, Daten zur antiken Chronologie und Geschichte (Stuttgart: Reclam, 1990).

Anna-Dorothee von den Brincken, Historische Chronologie des Abendlandes. Kalenderreformen und Jahrtausendrechnungen, eine Einführung (Stuttgart/Berlin: Kohlhammer 2000)

Ronald H. Fritze et al., Reference Sources in History: An Introductory Guide, 2nd Edition (ABC-CLIO, 2004)

ABBILDUNGSNACHWEIS

Folie 1: https://www.repubblica.it/scienze/2014/01/06/foto/archeologia_a_pompei_si_mangiavano_anche_le_giraffe-75276590/1/#1

Folie 9: https://www.giscloud.com/blog/gis-in-archaeology-mapping-roman-and-byzantine-ruins-case-study/

Folie 51: https://www.pinpng.com/pngs/m/339-3394082_want-to-live-a-legacy-life-here-are.png

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Folie 66: http://hyperphysics.phy-astr.gsu.edu/hbase/Nuclear/cardat.html

IMPRESSUM

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